Teachers' implementation and orchestration of Cabri-use in mathematics teaching

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Preface

When UiA, funded by the Norwegian research council, offered a 3 year full time position as Ph.D. student in a developmental research project, I saw it as a big opportunity at least in two ways. I wanted to learn more about implementation and use of ICT in mathematics teaching which the developmental project drew attention to. As I indicate in section 1.1, this was an area which had attracted and interested me for many years from my first experience with electronic computers more than twenty years ago. Secondly, to work in a team with experienced researchers and other Ph.D. students at UiA and having regular contact with teachers for several years attracted me. I was happy to get the position and started my Ph.D. study on the 1st of August 2004. I have now finalised my writing of this thesis which as the title indicates has a teacher perspective on computer software use.

There are many who deserve to be acknowledged for their support in my work for the last four years. I first want to thank the students and teachers. Most of the teachers participated together with me in the developmental projects for three years; they kindly welcomed me at their schools, provided me with copies of their teaching materials and found time for conversations and interviews. I want to thank all the Ph.D. students in mathematics didactics at UiA with whom I had extensive contact and discussed a scope of different themes. I want to thank the community of mathematics educators at UiA and teachers at the doctoral courses I attended: Barbara Jaworski, Simon Goodchild, Roger Säljö, Trygve Breiteig and Barbro Grevholm. I am very grateful that I have had the opportunity to be part of such communities with people with a variety of different expertise. I also give my thanks to my Faculty and to the Nordic Graduate School of Mathematics Education for support.

Great thanks go to my two supervisors, Anne Berit Fuglestad and Barbara Jaworski, who have supported me through the four years in supervision meetings, in written feedbacks to drafts of chapters and for all the encouraging and challenging comments.

Finally, my deepest thanks and gratitudes go to my wife Hilde and our lovely children Ragnhild and Benedicte which have given me daily encouragement, motivation and enjoyment. I also want to thank my family and my family-in-law for showing so much interest in the thesis.

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August, 2008

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Abstract

This thesis reports from a study of three teachers' first ever use of a particular computer software tool, Cabri, in teaching at two lower secondary schools in Norway. The thesis gives a characterisation of teachers' progression through a development process in which they implemented and orchestrated Cabri-use in their teaching. The study was situated within two developmental projects run by didacticians at the University of Agder. The teachers in the study participated in these projects together with a group of didacticians including the author of this thesis. Data were collected in sessions within this frame which included workshops at the University, visits to classrooms and computer labs at schools and different kinds of conversations with the teachers. *Activity theory* and the *instrumental approach* were used to conceptualise activity and analyse data.

Teachers' motives and goals for implementation of Cabri are analysed by utilising *activity theory*, building on the work of Leont'ev and Engeström. During the implementation process, the teachers worked in teams with other teachers and didacticians and raised many issues. A difference was evident in the kinds of issues considered and addressed by the teachers. The teachers at one of the school had a focus on institutional school related issues while the teacher at the other school had a focus on personal issues. From an activity theory perspective, the kinds of issues and teachers' ways of coping with them are seen to illuminate teachers' motives and indicate their goals for implementation of Cabri. Although issues raised in the study were particular to these teachers, the issues are argued to be relevant to teachers and educators more widely.

Analysis of teachers' orchestration of students' work with Cabri is also guided by the *instrumental approach* introduced by Trouche. In the instrumental approach, the term 'instrumental orchestration' accounts for the role of the teacher when computer software tools are used in mathematics teaching. In the thesis, teachers' emphases and ways of accomplishing their Cabri-teaching as well as how they arranged these lessons are considered as being part of teachers' orchestration of Cabri-use. Two kinds of orchestration are illuminated and their consequences for students' work and achievements with Cabri are discussed.

Overall, the thesis provides a contribution to research in mathematics teaching, and suggests implications for mathematics teachers considering implementation and orchestration of computer software tool-use in teaching. The thesis suggests that the established and evolving collaboration among mathematics teachers in schools influences to a great extent teachers' implementation of new tools and the sustainability of develop-

ment in mathematics teaching. Conclusions are presented indicating that implementation of a new computer software tool can offer teachers a medium to develop new styles of mathematics teaching. Implications are also suggested concerning future developmental projects aiming to support teachers' development in mathematics teaching.

Sammendrag

Avhandlingen rapporterer fra en studie av tre lærere på to ungdomsskoler i Norge som tok i bruk et dataverktøy, Cabri, for første gang i matematikkundervisningen. Det gis en beskrivelse av karakteristiske trekk ved lærernes utvikling fra de ble introdusert til Cabri og begynte å vurdere bruk av Cabri i undervisning til de implementerte og startet å bruke Cabri i matematikkundervisningen. Studiet av lærerne var knyttet til to utviklings- og forskningsprosjekt som ble ledet av didaktikere ved Universitetet i Agder. Lærerne i studiet deltok i utviklings- og forskningsarbeid sammen med didaktikere, inkludert forfatteren av avhandlingen. Data ble samlet inn innenfor denne rammen som inkluderte verksteder på universitetet, observasjon av undervisning i klasserom og datalab samt ulike typer samtaler med lærerne. To teoretiske perspektiv, *activity theory* og *the instrumental approach* ble benyttet til å teoretisere og analysere data.

Lærernes motiv og mål for implementering av Cabri analyseres med støtte av *activity theory* og bygger på arbeid av Leont'ev og Engeström. I implementeringsfasen jobbet lærerne i team sammen med andre lærere og didaktikere og diskuterte problemstillinger før verktøyet kunne tas i bruk i undervisningen. Avhandlingen dokumenterer et skille i hva slags type problemstillinger lærerne trakk fram og jobbet med i implementeringsfasen: På den ene skolen hadde lærerne fokus på institusjonelle problemstillinger, mens læreren på den andre skolen hadde fokus på mer personlige problemstillinger. Med støtte i *activity theory* argumenteres det for at typen problemstillinger og lærernes måter å håndtere disse på, belyser lærernes motiv og indikerer deres mål for implementering og bruk av Cabri i undervisningen. Selv om problemstillingene gjaldt for disse tre lærerne og arbeidssitasjonen deres, argumenteres det i avhandlingen for at problemstillingene også mer generelt er relevante for lærere, forskere og andre med ansvar for utdanning.

Analysen av lærernes tilrettelegging og støtte til elevene i arbeidet med Cabri gjøres ved bruk *the instrumental approach,* introdusert av Trouche. I dette teoretiske perspektivet introduseres termen 'instrumental orchestration' for å belyse lærerens rolle når dataverktøy brukes i matematikkundervisning. I avhandlingen argumenteres det for at det lærerne la vekt på i undervisningen, måten de gjennomførte undervisningen på samt hvilke grep som ble gjort for å organisere undervisningen, er inkludert i deres 'instrumental orchestration' for elevene. På bakgrunn av studiet presenteres og diskuteres to typer 'instrumental orchestration' og deres konsekvenser for elevers arbeid og prestasjoner med Cabri

Mer overordnet gir avhandlingen et bidrag til forskning på matema-

tikkundervisning, og det presenteres implikasjoner for didaktikere, utdanningsmyndigheter samt matematikklærere som vurderer å implementere og ta i bruk et dataverktøy for første gang. Avhandlingen peker på at varige endringer av matematikkundervisning på en skole støttes, dersom lærere jobber sammen for å utvikle matematikkundervisningen. Det konkluderes med at implementering av et nytt dataverktøy kan være et medium for å utvikle nye undervisningsformer for lærere. Videre presenteres implikasjoner for framtidige utviklingsprosjekt som har mål om å støtte læreres utvikling av matematikkundervisning.

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1 Setting the scene for the research study

1.1 Personal motives for the research study

As a student in lower secondary school in 1985/1986, I attended an optional electronic computer course. This was the first time ever this school offered use of electronic computer as a school subject. Together with approximately 20 other students we were placed in groups of 4 to 5 students around small Sinclair ZX Spectrum machines using Basic as programming language. This was my first meeting point with a computer in an educational setting. Although I remember to have experienced the course as boring, my curiosity for the electronic computer was born. The following year I attended a new electronic computer course, and together with friends spent time with programming and games using Commodore 64 personal computers at home. Later during my university education programme early in 1990s, I studied informatics for one year. I accomplished courses in informatics both related to construction of electronic computers, courses focusing on ability to use different kinds of software and courses emphasising the programming language Pascal. As part of my education programme in mathematics and later the master programme in mathematics didactics, use of computers was included both in numerical mathematics and through use of mathematical software. Hence, in my education I was introduced to, taught, practiced and accomplished courses related to use of electronic computers both in general and in particular related to mathematics.

My teaching practice is mainly from University of Agder[1] (UiA) as a lecturer in the teacher educational programme in mathematics. Most of my teaching duties at UiA have been in the intersection between mathematics and use of computer software. In addition I have taught several years in an optional one year study programme named ICT for teachers. This optional programme consists of two semi-annual full time parts, and is designed as an optional choice for students in their General Teacher Education[2] programme and for teachers who go through a further education. ICT for teachers emphasises educational use of computer software in different subjects in school, programming, Internet and several other themes. I have a limited experience as a mathematics teacher at lower and upper secondary schools. I had some school teaching practice as part of a one year pedagogical programme at UiA and from provisional posi-

[1] Ahead of the 1st of September 2007, University of Agder was not accredited as a university and had the name Agder University College, a name it got after a merging of several educational departments in 1994. To simplify, I will refer to University of Agder's official abbreviation UiA in the rest of the thesis.
[2] The General Teacher Education in Norway approves for teaching at Grade 1-10 in Norway.

tions alongside my studies at UiA where I used calculators in some lessons but never any computer software tools.

In my teaching practice at UiA I have used a number of computer software tools and experienced how students in the teacher education programme and teachers in schools consider use of computer software tools. I have also been in contact with many teachers both in primary and secondary schools, particularly teachers who were appointed as practice teachers for students in the General Teacher Education programme. Both I and the students often observed what I interpret as a lack of integrating ICT in mathematics teaching and other school subjects despite requirements for such kinds of use in the National Curriculum in Norway from 1997. I have even heard comments like: "It is nice to have students from UiA who can take the responsibility for the ICT part". Except for the comment in the previous sentence, I find confirmation of a similar moderate use of ICT when studying national surveys in Norway (see Kløvstad and Kristiansen (2004), Erstad, Kløvstad, Kristiansen, and Søbye (2005) and Arnseth, Hatlevik, Kløvstad, Kristiansen, and Ottestad (2007)). These surveys are considered in Section 2.2.1 and together with my personal experience stimulated questions such as: Why do we observe such slow progress in utilising computer software in mathematics teaching? Why are some teachers negative to the use of computer software in mathematics? What kinds of obstacles prevent teachers from implementing and using computer software in mathematics teaching? And if teachers use computer software in mathematics teaching: How and with what motives and goals do they use it? These are some of the questions which stimulated my desire to apply for the position as Ph.D. student in the KUL[3]-ICTML[4] developmental research project. I wanted to study how teachers were able to implement and use computer software in their teaching despite experienced obstacles.

In the following section I describe some characteristics and aims of the ICTML project and also refer to the KUL-LCM[5] project in which many of the same teachers and didacticians participated. We refer to the university educators and Ph.D. students as *didactician*` having the responsibility for theorising learning and teaching and considering relationships between theory and practice. The projects were run by didacticians at UiA for 4 years, from January 2004 to December 2007, and with

[3] KUL is an abbreviation for "Kunnskap, Utdanning and Læring" (Knowledge, Education and Learning)
[4] ICTML is an abbreviation for ICT and Mathematics Learning. The KUL-ICTML project is supported by the Norwegian research council (NFR no. 161955/S20). In the rest of the thesis I refer to this project as the ICTML project
[5] LCM is an abbreviation for Learning Communities in Mathematics. The KUL-LCM project is supported by the Norwegian research council (NFR no. 157949/S20). In the rest of the thesis I refer to this project as the LCM project.

participation from teachers from August 2004 till June 2007. It is within these two developmental projects that my research in mathematics teaching with computer software has been located. I continue the chapter by formulating aims and research questions for my personal research study with the ICTML project. I end the chapter by presenting an overall structure of the thesis.

1.2 A research study as part of developmental projects

The ICTML-project emphasises students' learning and development in mathematics within an ICT environment, teachers' competence in using ICT in their teaching and how use of ICT influences their teaching where the latter is my main focus:

> We will study the teachers' development of their own competence both in using the software themselves and in utilizing software in their teaching with students in an experimental and challenging way (Fuglestad, 2004a, p. 1)

The ICTML project was organised in collaboration with the bigger LCM project and shared similar theoretical grounding and goals as the LCM project. An intention from the didacticians point of view in the projects and in the design of particularly the LCM project, was to develop a community of inquiry (Jaworski, 2005; Wells, 1999). The *inquiry communities* included teachers in eight schools and didacticians at UiA including myself, all considered as learners. Didacticians in the projects aimed to create opportunities for teachers to develop and change their practice, based on a general aim of *improved learning* and *development* of *mathematics teaching*. This aim of the LCM project has been described in the following way:

> Learning Communities in Mathematics (KUL/LCM) is a project which aims to design and study mathematics teaching development for the improved learning of mathematics through inquiry communities between teachers and didacticians (Jaworski, 2004b, p. 33).

What this quotation emphasises is that the development of inquiry communities with teachers and didacticians was a proposed aid for design, study and in fact to promote development in mathematics teaching. In contributions discussing the LCM project, like in Jaworski (2007), the collaboration between teachers and didacticians has been described with references to Wagner's description of *co-learning agreement*:

> In a co-learning agreement, researchers and practitioners are both participants in processes of education and systems of schooling. Both are engaged in action and reflection. By working together, each might learn something about the world of the other. Of equal importance, however, each may learn something more about his or her own world and its connections to institutions and schooling (Wagner, 1997, p. 16).

In the projects, didacticians and teachers have been used as terms instead of Wagner's "researchers and practitioners", where use of the term didacticians has been very deliberate to recognise that *both* groups can engage in research. In the LCM and ICTML projects it has been acknowledged and emphasised that teachers and didacticians bring different expertise and engage in inquiry together to inform and develop their different practices. For the ICTML project, *implementation* of *computer software* in *mathematics teaching* was a proposed outcome of the co-learning between teachers and didacticians in the projects. The projects have emphasised three levels of learning communities:

- in learning mathematics;
- in teaching mathematics;
- in researching mathematics teaching and learning.

Alongside these three levels, three layers of *inquiry* have been defined:

- Inquiry in *learning* mathematics where teachers and didacticians explore mathematics *together* in tasks and problems in workshops, and eventually pupils in schools learn mathematics through exploration in tasks and problems in classrooms.
- Inquiry in mathematics *teaching* where teachers', in association with didacticians, use inquiry in *design* and *implementation* of tasks, problems and mathematical activities in classrooms.
- Inquiry in *developing* the *teaching* of mathematics, by *researching* the processes of using inquiry in mathematics, in teaching and in learning mathematics.

The projects were organised with workshops at UiA where teachers and didacticians participated. In the workshops, there was a focus on inquiry and collaboration processes often by grouping teachers together with didacticians in group sessions. Workshops in the ICTML project emphasised implementation and use of ICT in mathematics teaching. The workshops also included contributions from didacticians and teachers in plenaries where teachers typically presented experiences from teaching. School teams with participating teachers and at least one didactician, were another important level of collaboration. In these teams, the teachers were supposed to share ideas, plan and design lessons and consider lessons carried out. When the teachers carried out teaching in classrooms and computer labs, they were sometimes observed by didacticians and other teachers in the school team. Whenever it was found suitable and possible for both parts, the teaching sessions were followed by a meeting where the teacher(s) and didacticians(s) talked about the lessons and sometimes started to plan coming lessons. Workshops, school team meetings, conversations before and after observing lessons are examples of sessions where didacticians and teachers met and built *learning communities.*

The first workshops in the ICTML project focused on use of spreadsheets (Microsoft Excel) and dynamic geometry software (Cabri Geometry II Plus[6]). Later, also use of graph plotting software and Internet resources in mathematics were discussed in the workshops. In addition to the software listed above, the project intended to focus on other kinds of ICT tools such as computer algebra systems. When none of the invited upper secondary schools signed contracts for participation in the ICTML project, computer algebra systems were dropped. The decision to have a main focus on use of spreadsheet and dynamic geometry software was made based on considerations of software which would provide opportunity for explorations and inquiry in teaching and learning at the level of schools in the project. The decision was also based on requirements for use of spreadsheet in the National Curriculum and examinations in Norway. In the south western part of Norway, from where the projects were run and the teachers worked, more lately also dynamic geometry software, often Cabri, had gained some popularity. The decision to pay a main attention to these two computer software tools was also based on experience from a minor three year developmental project at UiA. This earlier project involved mathematics teachers from the same area of Norway working within ICT rich environment (Fuglestad, 2004b; 2007).

1.3 Aim of study and research questions

In my research I have studied the development of mathematics teaching emphasising the role of ICT with teachers attending the LCM and/or the ICTML project. More specifically, I have studied teachers' implementation and orchestration of Cabri-use in mathematics teaching. I use *computer software* as a term throughout my study. I also pay attention to how other artefacts were used to support the teachers' teaching with computer software tools. Such supporting artefacts both include teaching packages and compasses which were used by teachers alongside use of Cabri.

Before and in an early phase of the collection of data in my research study, I had an aim to contribute to an understanding of teachers' use of computer software in mathematics at Grade 8-10 in Norwegian lower secondary school. Gradually I reformulated my aim and phrased two research questions based on an elaboration of a theoretical framework and pre analysis of collected data including maps of data, critical reductions of data, transcriptions and coding. The collected data provided evidence for a case which emphasised how three teachers at two schools gradually implemented the dynamic geometry software package Cabri in their mathematics teaching for the first time ever in their teaching career. The research questions which eventually guided my research are:

[6] Later in the thesis I will use the short term "Cabri" when considering "Cabri Géomètre II Plus" as an example of dynamic geometry software

1) *With what motives and goals do teachers at Grade 8 implement and orchestrate Cabri-use in mathematics teaching?*
2) *What characterises teachers' initial orchestrations of Cabri-use in mathematics teaching at Grade 8?*

The questions relate to teachers' perspectives on implementation and use of Cabri in mathematics teaching. However, students' role and use of Cabri are crucial in a study of teaching, and concerns for students' achievements were addressed by the teachers both during planning of teaching and when teachers talked about their teaching. The term 'orchestrate', which is included in both research questions, are discussed in Chapter 2 and 3, while use of the terms 'goals' and 'motives' are discussed in Chapter 3.

The thesis is built around a case with Cabri and teachers who never had used Cabri in teaching. However I argue that my study is *not* just giving contribution and implications about implementation and use of Cabri as a computer software tool. The case is about how teachers through a developmental process implement and use a *new tool* in mathematics teaching at their schools.

1.4 The structure of the monograph

In this chapter I have presented a background and the two research questions guiding my research of mathematics teaching situated within two developmental projects, the ICTML and LCM project.

Alongside a literature review in Chapter 2, a number of terms related to my research concerning computer software use in mathematics teaching will be discussed. I indicate the status quo for use of computer software in teaching, and the external influence on use of computer software through National Curricula and developmental plans are outlined as a background for the research study.

Chapter 3 is devoted to the theoretical framework of my research study based on two theoretical learning perspectives. The activity theory perspective is elaborated by particularly emphasising contributions by Vygotsky, Leont'ev, Kaptelinin and Engeström. The 'instrumental approach to mathematics learning' is the second theoretical perspective I utilise in this thesis. The instrumental approach was proposed by Trouche based on what I denote as the general theory of instrumentation by Rabardel. In the thesis I propose that the two perspectives are complementary to each other. The instrumental approach to mathematics learning accounts for the role of computer software *use* in teaching and learning mathematics, while activity theory accounts for the institutional frame in which *implementation* of computer software in teaching takes part.

In Chapter 4, the methodology and research design for the research study is elaborated by emphasising the nature of the research within two developmental projects. The chapter emphasises the evolution of a case with three teachers in the project and their initial implementation and orchestration of Cabri-use in mathematics teaching, methods of data collection and analysis.

In Chapter 5 I analyse teachers' 'motives' for implementation of Cabri utilising the activity theory perspective. I emphasise Leont'ev's distinction between collective activity and individual actions, and the role of 'activity systems' when analysing teachers' implementation of Cabri as development in their teaching. In Chapter 6, teachers' management of Cabri-use in teaching are characterised by utilising the instrumental approach with an emphasis on teachers' 'instrumental orchestration' of students' work with Cabri. Both of the theoretical perspectives contribute to the analysis of teachers' goals which link teachers' motives for implementation of Cabri and operations in their teaching with Cabri.

Chapter 7 contains conclusions and implications for mathematics teachers, didacticians and policy makers. Contributions to research of mathematics teaching are presented considering personal and institutional issues concerning implementation of Cabri and characteristics of teachers' orchestration of Cabri-use in teaching. The role of developmental projects for development in mathematics teaching in schools is discussed.

2 Implementation and use of computer software in teaching

In Chapter 1 I presented what I intended to achieve in my research study situated within two developmental projects. As indicated in the title of the thesis and this chapter, ‘implementation’ and ‘use’ are two significant terms in this thesis. I study *implementation* and teachers’ orchestration of Cabri- *use* where Cabri is a computer software tool which the teachers in my study had never before used in their mathematics teaching.

I consider a teacher’s *implementation* of Cabri as a developmental process. I analyse the process of development in teaching from teachers’ first introduction to Cabri in workshops at UiA where they started to discuss possible use and what they wanted to achieve with use of Cabri in teaching. In follow up workshops and in school team meetings, the teachers started to address *issues* they needed to overcome in order to have a successful use of Cabri in teaching. Thus, implementation of Cabri was a process leading up to the three teachers’ orchestration of Cabri-use in mathematics teaching, but implementation and use do indeed also overlap. Teachers might start to use Cabri despite having faced issues in the implementation process. One such example is the issue of students’ lack of access to Cabri at home raised by one of the teachers in my study (discussed in Chapter 5).

When I refer to *use*, or to be more precise teachers’ *orchestration* of Cabri-*use* in teaching, it is the practice in classrooms and computer labs which is at stake. Through teachers implementation process decisions to use Cabri and adaptations to their school settings were made. However, I consider teachers’ *arrangements* for use of Cabri such as organisation of students and use of teaching packages as being part of their orchestration of Cabri-use. When the teachers talk about their teaching, both implementation and use of Cabri are considered which is evident in the analysis in Chapters 5 and 6. Later, in the introduction to the analysis chapters in Section 4.5, I consider my sources of data in respect to the difference between ‘implementation’ and ‘use’ which are emphasised in respectively Chapters 5 and 6.

This chapter is divided into three main sections. In Section 2.1 I relate my study of teachers’ perspectives when implementing and using computer software in mathematics teaching to requirements in the National Curricula in Norway. I refer to curricula for primary and lower secondary school from 1987 and 1997, curriculum for upper secondary school from 1994 with revisions from 1999 and 2000, and a new curriculum for primary and the whole secondary school from 2006. Since the main part of the data in my research study was collected during the school year 2005/2006, the teachers at lower secondary school in my study were guided by the requirements in the curriculum from 1997.

In Section 2.2 I indicate status quo for use of computer software and ICT in general in mathematics teaching in Norway and internationally. The main part of Section 2.2 contains a review of research literature considered to be related to implementation and use of computer software in mathematics teaching. Section 2.3 is devoted to an introduction to eight terms applied throughout the thesis in relation to my study.

2.1 External guiding of computer software use in school

The Norwegian Department of Education has for two decades tried to stimulate use of ICT in schools through requirements in National Curricula and national developmental plans for ICT use. Below, in Table 2.1, I list the National Curricula and plans in Norway quoted in this thesis:

Table 2.1: List of quoted National Curricula and developmental plans for ICT use

Description	Reference	Official abbreviation	Translations in the thesis
The National Curriculum 1987 (primary and lower secondary school)	KUD (1988)	M87	By the author
The National Curriculum 1997 (primary and lower secondary school)	KUF (1997)	L97	Official English version, Hagness and Veiteberg (1999)
The 1999 and 2000 revisions of the 1994 National Curriculum (upper secondary school)	KUF (1999; 2000)		By the author
The 2004 Programme for Digital Competence 2004-2008	UFD (2004)		By the author
The 2006 National Curriculum in mathematics (primary, lower and upper secondary school)	KD (2006)	LK06	Official English version, available on web[7]

Throughout the two latest decades, a number of terms such as ICT[8], IT, technology, data machines and electronic data processing machine[9] have been introduced in education. In the new National Curriculum in Norway which was effective from August 2006, LK06 (KD, 2006), digital tools is the official term.

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[7] Official English version of the Mathematics Subject Curriculum in LK06 is available on: http://www.udir.no/upload/larerplaner/Fastsatte_lareplaner_for_Kunnskapsloeftet/english/Mathematics_subject_curriculum.rtf

[8] ICT is in the Norwegian language named IKT based on the Norwegian spelling of communication (kommunikasjon)

[9] Abbreviated EDB in Norway

In M87 (KUD, 1988), learning to use “data” was included in the plan for mathematics. The next national curriculum for primary and lower secondary school, L97 (Hagness & Veiteberg, 1999; KUF, 1997), focused on integrated use of ICT in mathematics. ICT was not to be seen as a separate subject in the curriculum; instead ICT was supposed to be used as a suitable aid and tool in other school subjects. The term ICT included both use of different kinds of calculators, various kinds of electronic computer software tools such as spreadsheets and Internet as a resource in all subjects. L97 also included statements concerning use of a particular kind of software in mathematics. In the section on subject-related objectives for the lower secondary stages (Grade 8-10,) related to the topic “handling data”, use of spreadsheets is mentioned:

English version	**Norwegian version**
Pupils should be acquainted with various uses of statistics. They should be able to find, interpret, evaluate and present information and data. They should be able to use databases and spreadsheets and other computer software. On the basis of their practical experience, pupils will acquire concepts relating to probability (Hagness & Veiteberg, 1999, p. 178).	Elevene skal kjenne til ulik bruk av statistikk. De skal kunne skaffe fram, tolke, vurdere og presentere informasjoner og data. De skal kunne nytte databaser, regneark og andre dataprogrammer. Elevene skal med utgangspunkt i praktiske erfaringer tilegne seg begreper om sannsynlighet (KUF, 1997, p. 166).

Figure 2.1: Statement in the National Curriculum L97

The national curriculum for upper secondary school from 1994 presents statements about use of IT in the teaching. In the revisions of the curriculum, KUF (1999; 2000), use of what they denote as ‘technological tools` was located in two main subject elements named, ”Modelling, experimenting and investigation” and ”Culture, language and communication”. The emphasis was mainly on use of technological tools in *investigations* and *problem solving*. Below is an example from the descriptive text and the underlying key point 2c) of the main subject element: ”Modelling, experimenting and investigation” at Grade 12. The statements are part of the mathematics course called 2MZ, where the word *they* refers to the students:

English version (own translation)	**Norwegian version**
They are supposed to be able to use technological tools in an appropriate way in modelling, investigation and problem solving: 2c) be able to use technological tools in investigation and problem solving	De skal kunne bruke teknologiske verktøy på en hensiktsmessig måte i modellering, utforsking og problemløsing 2c) kunne bruke teknologiske verktøy i utforsking og problemløsing

Figure 2.2: Statement in KUF (2000, p. 18)

For more than twenty years, the Department of Education in Norway has designed national developmental plans for IT/ICT use in Norwegian schools. Below is an example from the 2004 plan. This plan (see Table 2.1) defines 'digital competence' as term in national plans in Norway:

English version (own translation)	Norwegian version
The Department defines digital competence as the competence which bridges skills such as reading, writing and calculation and the competences which are needed to be able to use digital tools and medias in a creative and critical way	Departementet definerer digital kompetanse som den kompetansen som bygger bro mellom ferdigheter som å lese, skrive og regne og den kompetansen som kreves for å ta i bruk nye digitale verktøy og medier på en kreativ og kritisk måte

Figure 2.3: Statement in UFD (2004, p. 5)

The same document refers to ICT as a "learning tool to strengthen the quality of education, create good learning strategies and strengthen the learning outcome " (UFD, 2004, p. 15).

In the LK06 (KD, 2006) national curriculum for primary and the *whole* secondary school in Norway, ability to use 'digital tools' is referred to as one of five basic skills in all school subjects. The other four basic skills are ability to express oneself orally, read, calculate and express oneself in writing. In mathematics, ability to use digital tools is defined in the following way:

English version	Norwegian version
Being able to use digital tools in the mathematics subject involves using these tools for games, exploration, visualisation and publication, and also involves learning how to use and assess digital aids for problem solving, simulation and modelling. It is also important to find information, analyse, process and present data with appropriate aids, and to be critical of sources, analyses and results(p. 4 in the English version available on web[7]).	*Å kunne bruke digitale verktøy* i matematikk handlar om å bruke slike verktøy til spel, utforsking, visualisering og publisering. Det handlar òg om å kjenne til, bruke og vurdere digitale hjelpemiddel til problemløysing, simulering og modellering. I tillegg er det viktig å finne informasjon, analysere, behandle og presentere data med høvelege hjelpemiddel, og vere kritisk til kjelder, analysar og resultat (KD, 2006, p. 4-5).

Figure 2.4: Statement in the mathematics part of LK06

LK06 contains aims referring to competences where use of digital tools typically is mentioned in combination with competences in using non-digital tools. As an example, the expected competence after Grade 10 in the topic "Number and algebra" is:

English version	Norwegian version
- use, with and without digital aids, numbers and variables in exploration, experimentation, practical and theoretical problem solving….(p. 6 in the English version available on web[7])	- bruke, med og utan digitale hjelpemiddel, tal og variablar i utforsking, eksperimentering, praktisk og teoretisk problemløysing…(KD, 2006, p. 9)

Figure 2.5: Statement in the mathematics part of LK06

The statement concerning *use of ICT in an investigative way* or similar expressions is common for the quoted curricula from 1997, 1999, 2000 and 2006. Requirements concerning use of ICT in the new curriculum, LK06 seem tightened. In LK06, “digital tool” and “digital aids” are used together with a number of explorative terms such as investigations and experimentation exemplified in the quotation above. The quotations above from LK06 indicate that the term ‘digital tools’ in LK06 mainly is a reference to different types of equipment such as computers, computer software and calculators and technical equipment like smart board and video projector. This is close to Fuglestad (2006)’s interpretation of ‘digital tools’ in LK06: “digital tools mean computers, calculators and digital equipment” (Fuglestad, 2006, p. 121). LK06’s use of the term ‘tool’ seems to be a characterisation of different types of equipment while research literature often uses the term tool when considering users’ use of for example computer software or calculator.

In UFD (2004), ‘digital competence’ is described as the competence which bridges skills in using digital tools and other basic skills. The term ‘competence’ is not used explicitly in this manner in LK06. I believe that the definition presented in UFD (2004) refers to an important competence for students but I find it a bit confusing to interpret the competence as being a *digital* one? In my view, abilities to combine different skills could rather be denoted as a multi skill competence, not restricted to be a digital related skill.

In the rest of the thesis I will refer neither to digital tool nor digital competence as terms since they are fairly new in Norwegian schools. I will neither use ICT nor technology except when referring to research applying these as terms. In my study, I restrict myself to have a main focus on Cabri as an example of computer software tool in mathematics teaching. Thus, *computer software* applied as a term in my study covers only part of the term *ICT* used in L97 and the terms *digital tool* and *digital aids* used in LK06.

My main collection of data was during the school year 2005/2006. Thus, when the teachers in my study refer to the curriculum they talk about *L97* since LK06 was effective from the school year 2006/2007.

2.2 Computer software implementation and use in teaching

In a survey on research literature concerning use of ICT in mathematics education, Lagrange, Artigue, Laborde, and Trouche (2001) argue for increased emphasis on the teacher in research in this area. They argue that many studies have been concerned with students’ mathematical learning mediated by ICT, but fewer studies have focused on teachers’ roles and practices. Five years earlier, Noss and Hoyles (1996) in a similar way referred to a limited emphasis on the teacher perspective within research of mathematics teaching in classrooms. When considering studies emphasising technology and the teacher, Monaghan (2004) argues that these "have largely focused on teachers' beliefs and forms of teacher knowledge" (p. 330), and he refers to a limitations with such studies that they "by design, miss the wholeness of teachers' practices" (p. 330).

My case study, described in Chapter 4, was situated within two developmental projects and emphasises three teachers' implementations and orchestration of Cabri-use for the first time in their teaching career. What kinds of obstacles and issues did the teachers experience when making efforts to implement computer software guided by statements in the curriculum? What did the three teachers want to achieve? These are just two of many questions which can be raised concerning implementation and use of computer software in mathematics teaching.

This section includes a literature review in the area related to teachers' implementation and use of computer software in teaching which the quotes above indicate need attention in research. In particular, I consider implementation and use of dynamic geometry software, in the rest of the thesis abbreviated as DGS, into mathematics teaching. How can and have these studies contributed to my own design of research and to approach the later analysis? What kinds of critical issues have been emphasised in earlier research into this area? What are crucial elements for a successful implementation of computer software in mathematics teaching? Later, when presenting findings from my study I hope to contribute to the field, both in supporting earlier findings and by offering some new ones.

2.2.1 The position for computer software use in teaching

In national surveys in Norway, planned to be accomplished every second year starting in 2003, status quo concerning use of computer software in Norwegian schools is reported (Arnseth, Hatlevik, Kløvstad, Kristiansen, & Ottestad, 2007; Erstad, Kløvstad, Kristiansen, & Søbye, 2005; Kløvstad & Kristiansen, 2004). The surveys are based on questionnaires involving what Kløvstad and Kristiansen (2004) denote as a "representative sample" of students and teachers at Grade 7, 9 and 11, principals, parents and ICT resource people at schools.

In Section 2.1, I referred to what I consider as quite extensive statements concerning use of computer software and other kinds of ICT tools in the National Curricula and other official documents for schools in Norway. However, the surveys quoted above report on a slow development in the use of ICT in different school subjects. Erstad et al. (2005) present findings which still indicate limited use and influence of digital tools on learning in school subjects. Such a slow progress is also evident for mathematics, despite developmental plans for ICT/IT use in Norwegian Education, and the Government's design of National Curricula which for more than ten years have contained requirements concerning use of ICT in mathematics teaching. Thus, the efforts from the Government to include use of computer software in mathematics teaching have not yet led to the proposed development and changes.

The Norwegian Directorate for Education and Training[10] is the executive agency for the Ministry of Education and Research in Norway and responsible for the development of primary and secondary education. The Directorate has made efforts to stimulate use of computer software in the final school examination in mathematics at Grade 10. The examination in mathematics is composed of two parts: one oral and one written. Schools and students have had the possibility to choose whether or not they want to use a spreadsheet in part of the written examination.

Schools in Norway have also been asked to design their own ICT plan, meant to comprise important steering documents for schools, teachers' development and improved learning for students. But have they really been helpful documents for development of teaching and improved learning in mathematics? Experiences from other countries indicate that such plans often have failed to be successful. According to Thomas (2006), one reason for this is the typical general form of the plans. Thomas argues that statements like: "Technology should be used wherever possible as an aid to learning" and "All teachers are expected to integrate ICT into their teaching and learning practice" (Thomas, 2006, p. 271) rarely have the effect they aimed to have. Thomas (2006) argues that the ICT plans rarely point to *professional development of teachers* or priority on *particular software* which he argues to be more useful. Without going into an analysis of ICT plans made by Norwegian schools, at least the statements in L97 concerning integrated use of ICT whenever suitable has such a rather general form.

Kløvstad and Kristiansen (2004) report of an increased access to computers in Norwegian schools over many years (an average of 7 students per computer at Grade 9 in 2003), and that most principals in Norwegian schools emphasise priority on ICT use in schools. However, despite increased access to hardware and software applications and continually expressed expectations from governments and school leaders, Erstad et al. (2005) report a lack of regularity in utilising ICT in mathematics teaching. These findings from Norway are also supported by studies in countries outside Norway. In fact, Lagrange, Artigue, Laborde, and Trouche (2001) refer to a similar slow evolution in most countries. Trouche (2005b) refers to a lack of frequent use of ICT even among

[10] The Norwegian Directorate for Education and Training was established in June 2004 and is the official translation of what in Norway is called Utdanningsdirektoratet.

teachers in France who chose to take part in a developmental programme concerning ICT use in mathematics. Considering development over time, Thomas, Tyrell, and Bulloch (1996) and Thomas (2006) report from comparison surveys revealing how teachers' use of computers in mathematics teaching has developed over ten years (1995 to 2005) in New Zealand. Although gradually more and more teachers spend time on using computer software, and new possibilities have been given by the introduction of for example interactive whiteboards and video projectors, the teaching with and without computer software or other ICT tools look almost unchanged. Such reproduction of teaching is also expressed below in the quotation from a study in United Kingdom:

> Classroom teachers are simply using the technology to do what they have always done, although in fact they often claim to have changed their practice (Hennessy, Ruthven, & Brindley, 2005, p. 156-157).

Hennessy et al. report that many teachers are aware of and do reflect over new forms of activity, resources, and strategies for mediating ICT-supported subject learning in their classrooms. However, at an overall level few changes in teachers' practice were observed. They report of an apprehension among a number of teachers that students' use of ICT will weaken theirs "basis knowledge" in mathematics. More positively, they do also report some progress in respect to the ways teachers utilise, or at least consider to utilise ICT tools in their teaching.

Hence, even recent studies present findings indicating that teachers' use of technology such as computer software is developing slowly, perhaps more slowly than some teachers themselves believe as argued in the quotation above. This supports my initial comments in Section 1.1 based on experience from contact with teachers through teacher education programmes at UiA. My experience based on contact with at least 50 mathematics teachers at lower secondary school over the five latest years, is that the main and often the only computer software used in mathematics teaching at lower secondary schools in Norway is spreadsheet software, for example Microsoft Excel. The teaching was often organised as a course to learn to use the tool as such, emphasising the menu system and what Excel affords. The observed lack of development in utilising computer software in mathematics teaching indicates that it is worthwhile with research focusing on the teachers. After all, it is the teachers who are expected to take responsibility and carry out use of ICT in mathematics teaching according to statements in the National Curriculum.

2.2.2 External statements offering a double challenge

Why is the implementation and impact of computer software in teaching progressing so slowly, or at least more slowly than proposed by the school authority? In Section 2.1, I referred to statements in the National

Curricula in Norway from 1987, 1994, 1997, 2000 and 2006. Typically, the statements concerning use of computer software are closely associated with an explorative and investigative approach to mathematics, and to integrate use of computer software in different school subjects as proposed in L97. In LK06 the first aspect is explicitly emphasised, as illustrated in Figure 2.4 and 2.5 in Section 2.1, with reference to terms like investigation, visualising, problem solving, simulation, modelling and experimentations. Hence, teachers' are asked to undertake what I denote as a *double innovation*:

- To implement computer software which for many teachers are fairly new tools in mathematics teaching compared to for example use of ruler, compasses and textbooks.
- To apply the computer software with a particular approach like investigation, visualising etc listed above. Such an approach could, for many teachers, be experienced as new in teaching and also different from how they themselves have been taught.

Barzel (2007) has a similar concern referring to "new teaching methods and integrating computers" (p. 77) as two challenges teachers are facing.

In Norway, use of software like Excel has often been taught in the form of a general course[11] not particularly mathematics related. These courses were originally designed for secretaries and other employees in trades, aiming to develop humans' formal competence in using Excel (and similar competences in word processing, internet use and so on). These or similar courses emphasise skills in using the software per se and not with a particular mathematical purpose. It also relates to the issue of applying software like Excel, not originally designed with the aim of being used in teaching.

Hence the statements in the National Curricula and other official documents for use of computer software in particular ways, open up situations which are difficult to control for teachers. The suggested approach could lead to many questions from students, especially if the approach to teaching with computer software provokes working conditions unfamiliar for them.

The teachers in my study participated in the LCM and ICTML developmental projects. The ICTML project emphasised use of computer software in mathematics teaching, and shared with the LCM project an emphasis on inquiry approach to teaching and learning of mathematics (Fuglestad, 2008). Thus, similar as the proposed *double innovation* in the Curriculum, teachers who participated in the ICTML project were offered a double innovation expectation: Use of computer software with *inquiry* approach.

[11] These courses are in Norway named the Data card, "Datakortet"

2.2.3 A lack of emphasis on pedagogical implications

In the previous section, I argued that teachers in Norway have been given requirements in the National Curricula about ways of using computer software in mathematics teaching which many teachers experience as unfamiliar. Indeed, a number of research papers emphasise that pedagogical implications of technology for mathematics teaching has been underestimated. Goos, Galbraith, Renshaw, and Geiger (2003) phrase such lack of considerations concerning the complex demands offered teachers and students when challenged to implement computer software in mathematics teaching:

> The introduction of technology resources into mathematics classrooms promises to create opportunities for enhancing students' learning through active engagement with mathematical ideas; however, little consideration has been given to the pedagogical implication of technology as a mediator for mathematics learning (Goos, Galbraith, Renshaw, & Geiger, 2003, p. 73).

One implication of this statement is awareness that mathematics changes and is represented differently with computer software. This is a view emphasised by Dörfler (1993):

> In general, substituting one tool for another one causes a change of the objects to be worked with and upon. Therefore not only the structure and form of the activity but its content are changed by introducing new tools (Dörfler, 1993, p. 163).

What these quotations highlight seem to be in accordance with concerns claimed by Vygotsky who emphasises that the tool used in mathematics transform the ways of working and reasoning (Vygotsky, 1978). Hence this could explain the suggested approach with computer software proposed in the curriculum (see Section 2.2.2). However, how helpful are such statements and their suggested approaches for the teachers? The claim by Goos et al. might indicate that it becomes too difficult a task for many teachers to use computer software in the proposed way as a long as the proposed way is so unclear. What does it mean to use, for example, a spreadsheet package like Excel in an investigative way? What kinds of tasks would be appropriate to use, and how can teachers manage to assist all the students during the lessons?

In a study of mathematics teachers' use of digital technologies in their mathematics lessons, Monaghan (2004) presents findings indicating that teachers are unprepared, for what he denotes as the *transformation* of mathematics when computer software are used. The study reported in his paper was situated within a project in the United Kingdom consisting of researchers and thirteen mathematics teachers implementing technology like computer software in their mathematics teaching. One of the software package used was spreadsheet (Excel), and the paper points to how the teachers experienced problems with transformation of calculations in mathematics to formulas and formats to apply in Excel. Monaghan describes teachers' design of worksheets which, particularly in an early phase, typically emphasised students' management of the computer software per se. Later, as a next step, the teachers had more focus on how to do mathematics with the software. Based on this Monaghan argues:

> There is a sense in which this is quite a natural development: if you want to do mathematics on a computer package, you first have to learn how to use the package (Monaghan, 2004, p. 342).

One way to stimulate this first phase is to apply a structured teaching package in their teaching with computer software. This also corresponds to how teachers often have worked with the tool in an initial phase themselves. In Norway such a structured teaching package, supposed to be worthwhile to use in mathematics teaching with spreadsheet at lower secondary school, was designed in 2003. The package (see Grongstad and Tveito (2003)) was made by two teachers based on a request by a forerunner[12] to the Norwegian Directorate for Education and Training. The package is available on the webpage[13] of the Directorate and on the webpage for the biggest labor union for teachers in Norway. An issue related to emphasise "to learn how to use package", as it is phrased by Monaghan in the quotation above, is to which extent it helps to prepare students for doing mathematics with the software and whether teachers find time for the latter.

As commented in Section 2.2.2, both the National Curriculum in Norway and the ICTML project suggested that teachers used computer software tools in ways described with terms such as investigative, explorative and inquiry. I considered this as a double innovation suggestion since it involved what would be two new or rather new elements in their teaching. Monaghan (2001) is critical to policy makers and researchers claiming for the uniqueness of ICT technologies in proposing changes in mathematics teaching saying:

> Researchers and policy makers should be looking at how the curriculum and school structures might allow for new roles for teacher-student interaction – with and without ICT (Monaghan, 2001, p. 390).

Mumtaz (2000) pays attention to how teachers could be supported in their take-up of ICT. She argues that the school as an institution typically gives too little time and support for teachers' development of ICT-use in teaching. Such concerns illustrate a potential need for developmental projects like the ICTML project. Firstly, to support pedagogical development of computer software use and use of other ICT tools in mathematics teaching as required by the Government in national curricula. Secondly, top have more attention in research on the developmental

[12] This was one of the forerunners to the Norwegian Directorate for Education and Training is known by the name "Læringssenteret"

[13] http://www.utdanningsdirektoratet.no

phase of teaching with computer software. The latter refers to an area in the research of mathematics teaching, teacher change and development of teaching, which according to the Handbook of International Research in Mathematics Education from 2002 (English, Jones, Lesh, Tirosh, & Bussi, 2002) has a short history. A number of typical small scale case studies have been made with increased emphasis on professional developmental programs to study the developmental process as phrased in Chapter 30 in the quoted Handbook. The ICTML and LCM projects are examples of such developmental programs or projects, where my study particularly relates to the ICTML projects and teachers' development concerning implementation and orchestration of computer software use in mathematics teaching.

Already in 1992, Kaput (1992) emphasised that research concerning implementation of technology at that time lacked emphasis on pedagogical implications. In this section (2.2.3), the complex tasks given teachers within schools concerning pedagogical implications of computer software tools have been considered. Quoted research literature has questioned the statements presented in the curriculum and the speciality of ICT emphasised by policy makers and many researchers. In the next section I refer to research literature emphasising what potentially prevents teachers from implementing and using computer software successfully, particularly the influence of the school as an institution.

2.2.4 Issues related to computer software implementation

With reference to a number of research papers, Goos (2005) points to a list of potential *issues* influencing implementation of technology. Most of the issues refer to what Lagrange, Artigue, Laborde, and Trouche (2003) classify as the *institutional dimension*. The issues emphasise the critical role of the school institutions and context when researching implementation of technology in mathematics teaching:

> skill and previous experience in using technology; time and opportunities to learn (pre-service education, guidance during practicum and beginning teaching, professional development); access to hardware (computers and calculators), software, and computer laboratories; availability of appropriate teaching materials; technical support; support from colleagues and school administration; curriculum and assessment requirements and how teachers interpret these for students perceived to have different mathematical abilities; knowledge of how to integrate technology into mathematics teaching; and beliefs about mathematics and how it is learned (Goos, 2005, p. 38-39).

In her paper, Goos calls attention to how such *issues*, which according to Artigue (1998) serve as *obstacles* for integration of technology, can be studied and analysed applying a socio-cultural perspective. Goos argues that such kinds of studies should occur within a context where the researcher has the possibility to study teachers' development over time, in her situation a four year project with pre-service and beginning teachers.

Based on a study of some teachers integration of Cabri, Assude (2005) discusses *time* as a key issue in teachers integration of ICT not been given sufficient emphasis in research. In her analysis, she distinguishes between three main kinds of time:

- *The didactic time* as the scheduling of time related to mathematical topics in the curriculum.
- *The time capital* as the total available time for mathematics for example in a school year.
- *The pace* as the rate of didactic time relative to the portion of the time capital used.

She discusses how teachers critically consider how time is spent efficiently giving the following example:

> Management of this time capital by the teacher takes into account the estimated temporal cost of each activity and the global time of all activities put together. For example, a teacher may deem a particular problem-solving activity a waste of time, since the temporal cost of implementing it is very high compared to all situations put together. Another activity may be seen as time saving, since it does not require spending too much of the time capital (Assude, 2005, p. 185).

In discussing the use of ICT tools such as Cabri, Assude also refers to the *tool time* as being part of the time capital. The tool time is the time needed for students to be used to the tool and to be able to use the tool.

> How does the teacher manage these different times in the classroom? We propose that the teacher views the time he has available indeed as a certain capital, which can be used (invested) in different ways. He makes decisions based on his assessment of the costs of relations such as the relation between tool time and didactic time, … , in view of saving as much time capital as possible, whilst promoting didactic time and pupils' learning time (Assude, 2005, p. 186).

Assude argues that the management and control of the didactic time is a great challenge for teachers, in particular when using a new powerful tool like Cabri for the first time in teaching. In her study, she found that the teachers' ability to control the didactic time increased when using Cabri for the second time the year after. Then teachers were able to make *time saving actions* based on experience the first year. One of the time saving action observed, was to "familiarize pupils with mathematical objects that appeared problematic for students in the first year, prior to the lessons with Cabri" (Assude, 2005, p. 195). Assude exemplifies with diagonals which had provoked problems the first year. Many students had not remembered what a diagonal was which generated many question when using Cabri and much time was spent. The second year teachers made time saving actions repeating the term diagonals ahead of utilising diagonals with Cabri.

With reference to a developmental project with teachers in France, Laborde (2001) reports findings emphasising a lengthy process for teachers to integrate DGS in their mathematics teaching. She discusses the *role of tasks* in mathematics teaching with DGS emphasising how hard it is for teachers to go beyond textbook tasks. Use of new tools in teaching, such as a computer software tool, presupposes a need to develop new kinds of tasks. Laborde (1993) emphasises this when arguing that the change of tools led to a need for different performance of tasks. Consequently teachers' are given a great challenge in order to organise the use of a powerful computer software tool like Cabri.

Monaghan (2004) argues that 11 out of 13 high school mathematics teachers in his study were able to put away their textbooks in their technology based lessons. Students' work with technology was based on tasks in worksheets which "emphasised students' management of the computer software per se" as I phrased it in the previous section (see p. 37). Monaghan also describes a typical pattern of work observed:

> short introduction to the task, worksheets which directed student activity, teacher circulating around the class ensuring the students were working and attending to mathematical or technical issues (Monaghan, 2004, p. 336).

In Laborde (2001), the role of tasks is exemplified by referring to integration of DGS similar to my study with implementation of Cabri. She refers to development in tasks applied on a scale from almost traditional geometry tasks, to tasks which could only be approached in a dynamic geometry environment. By traditional geometry tasks she refers to tasks typically applied in a paper-and-pencil environment often supported by a textbook and by applying available tools such as compasses and ruler. To use Cabri on such tasks basically only changes the drawing facilities. Teachers' emphasis of links between tasks in textbooks and tasks used in computer software or with other kinds of ICT tools is also evident in Graham and Thomas (1997).

Assude (2005) reports that the teachers typically worked with *compasses first and then with Cabri*, trying to integrate use of compasses and Cabri without "any major changes with regard to the broad types of tasks: construction, description and property identification" (p. 192). Ruthven (2007) describes different approaches applied by teachers when managing students' work with the software. His findings indicate that teachers' ways of orchestrating students' work with DGS vary; from trying to *minimise* difficulties of the software and emphasising the similarities with static pencil-and-paper geometry, to teachers who *optimise* difficulties and possibilities with the software. Analytical findings presented later in this thesis indicate that for two of the teachers in my study similarity in tasks and emphasis in lessons with Cabri and compasses was a desired choice. This indicates efforts to minimise students' difficulties with Cabri.

It is well-known that development in teaching takes time partly because of the institutional dimension emphasised earlier in this section (2.2.4). Kerr emphasises the extra challenges concerning development related to technology because of the speciality of technology:

> But our experience to date suggests that technology is qualitatively and quantitatively different from other kinds of classroom innovations, that it requires a radical shift in both teaching style and the teacher's vision of what classroom life is all about (Kerr, 1996, p. 24).

What Kerr says is that technology requires *different teaching style* and views of "what classroom life is all about". However in her Ph.D. Thesis from 2001, Margaret Kendal argues that individual teachers' use of technology in mathematics lessons usually is *consistent* with their teaching practices in non technology lessons. Findings indicating a similar tendency are presented in Cuban, Kirkpatrick, and Peck (2001), Kendal and Stacey (2001), and in Monaghan (2001) quoted in the previous section. In a study emphasising two teachers, Kendal and Stacey (2001) conclude that the two teachers' ways of utilising technology in mathematics teaching, in their study of Computer Algebra Systems (CAS), was consistent with each of the two teachers usual approaches to mathematics teaching in non technology lessons. Although they used the same curriculum material in technology lessons, their approaches with the material differed in accordance with their usual approaches to mathematics teaching:

> Both teachers intended to teach the same curriculum material in the same way but they made different pedagogical choices from the range of options. They had fundamentally different conceptions of mathematics with associated teaching approaches and innate privileging which influenced their particular choices while using technology, about what to emphasize, and how to incorporate the graphical and symbolic algebra capabilities of the calculator into their lessons (Kendal & Stacey, 2001, p. 162).

Thus, while Kerr argues for a necessary change in teaching style when introducing technology in mathematics teaching, Kendal and Stacey rather argue that criteria for such changes are rooted within a teacher's more general style of mathematics teaching.

Concerning teaching style, teachers' goals and how technology use affect social interaction in teaching, Monaghan (2004) found that when teachers used technology in mathematics lessons, they spent more time speaking to two students or small groups of students and less time speaking in plenary to all of the students. An earlier presented quotation from Monaghan's paper (see Section 2.2.3, p. 37) emphasised teachers' focus on students' learning of "how to use the package" in an initial phase of work with a piece of computer software package. In his analysis, he interprets the observed practice of the teachers to indicate that an "emergent goal" energising their teaching was "to ensure that technical difficulties did not prevent students attending to the task." (p. 344). Findings from the quoted studies in the last paragraphs indicate that a personal issue for development in teaching is a teacher's teaching style.

In United Kingdom, Crisan, Lerman and Winbourne (2007) have conducted a case study involving seven mathematics teachers where they studied factors influencing implementation of ICT in mathematics teaching. In the case study, they applied lesson observations, interview and other kinds of conversations. They argue that the majority of studies considering implementation and integration of ICT into mathematics teaching have been situated within classrooms with rich technology use. To complement this noted imbalance, Crisan et al. instead followed practising mathematics teachers in some secondary schools which they do not describe as working within technology-rich classrooms. Another important point for the researchers was the relationship between teaching with and without ICT:

> Most importantly, we intended to treat the teaching of mathematics and ICT use as interwoven aspects of a teacher's practice, which we identified as a deficit of the studies reviewed (Crisan et al., 2007, p. 23).

Above I have quoted a number of research papers supporting similar statements as this by Crisan et al. such as Kendal and Stacey (2001). Kendal and Stacey conclude that teachers' ways of utilising technology in mathematics teaching was consistent with their approaches to mathematics teaching in non technology lessons.

I started this section (2.2.4) by quoting Goos (2005) who points to a list of potential *issues* influencing implementation of technology which was argued to be dominated by institutional and contextual issues. Crisan et al. (2007) have also identified a number of issues influencing implementation of ICT in mathematics teaching which they classify as contextual and personal factors. They list altogether eight different kinds of *contextual fact*ors evident from their analysis of teachers' practices with ICT in mathematics teaching:

- The school context
- The mathematics departments: availability of and accessibility to ICT facilities
- The mathematics departments: availability to ICT resources
- Departmental ICT ethos
- Key persons promoting ICT within the department
- Teachers' ICT skills
- Teachers' ICT professional development
- ICT within the mathematics scheme of work

The same authors list five kinds of personal factors influencing teachers' implementation process of ICT in mathematics teaching:

- ICT content conceptions
- ICT curricular conceptions
- Conceptions of mathematics
- Pedagogical conceptions of mathematics
- Teachers' own learning experiences with the ICT applications

The earlier references to issues and above to factors involved in implementation of computer software tools both emphasise critical elements involved when teachers struggle to implement a new computer software tool in their teaching. In her Ph.D. thesis, Engström (2006) analyse three teachers use of Cabri in mathematics teaching, two from Sweden and one from Switzerland. Engström (2006) argues that a crucial point for teachers is to *dare* to use Cabri and other kinds of computer software tools investigatively. Thus, in her study the main emphasis is on what Crisan et al. (2007) consider as the *personal factors* influencing teachers' implementation process of Cabri and not the *contextual factors*.

Finally I want to add on "Teachers' own learning experiences with the ICT applications" and "Teachers' ICT skills", respectively one of the personal and one of the contextual factors set out by Crisan et al. (2007). When teachers' express low level of confidence in using computer software in mathematics teaching, researchers sometimes explain such a finding with reference to *teachers' computer anxiety* (Russell & Bradley, 1997). Based on analysis of a questionnaire of 350 Australian teachers, Russell and Bradley found that one third of the teachers experienced the computer as a source of anxiety. Among several factors, the anxiety was related to an experienced low level of own computer competence with tasks involved in using computers, and embarrassment associated with inappropriate use of computers. So when teachers express lack of ICT skills and faith in own capability to develop their ICT skills, it could be an indication of computer anxiety as I later argue in my analysis in Chapter 6.

2.2.5 Implementation of new tools in mathematics teaching

In Section 2.2.3 I quoted Monaghan (2001) who is critical of policy makers and researchers who claim for uniqueness of ICT technologies in proposing changes in mathematics teaching. An implication of Monaghan's statement is to consider more broadly teachers' implementation of *new tools* in their teaching where the computer software tool Cabri is the example considered in my study.

Berry, Graham, Honey, and Headlam (2007) consider issues arising when teachers for the first time adopt a tool in their teaching. They report from a study of teachers who were introduced to graphical calculators and supposed to utilise them in their teaching within their department. Thus, for these teachers graphical calculators were a new tool which they never had used before in their mathematics teaching. Berry et al. list seven kinds of recommendations to other schools who considered introducing graphical calculators. The recommendations are in the abstract of the paper summarised with three points:

> These recommendations were (i) that the department should have an action plan which describes where and why the calculators are to be used (ii) both initial and on-going training is necessary (iii) appropriate support in the form of both teaching resources and hardware should be readily available (Berry et al., 2007, p. 159).

In a review of literature concerning teachers' use of ICT, Mumtaz (2000) refers to "three interlocking factors that affect teachers' take-up of ICT" (p. 335): institution, resources and the teacher. The recommendations suggested by Berry et al. seem closely related to these three factors.

2.2.6 Teachers commenting their computer software teaching

In several recent studies concerned with computer software implementation and use in mathematics teaching, research has been designed to include an emphasis on *teachers' talking about* their experience from teaching with computer software, like the already quoted Goos (2005) and Crisan et al. (2007). Ruthven (2007) also asks for more account to be taken of teachers' ideas concerning integration of computer based tools in mathematics, in a study exemplified with dynamic geometry.

Both Hennessy et al. (2005) and Engström (2006) ask for attention in research to examples from *teachers' successful implementation and use* of computer software. In the already mentioned study by Engström (see Section 2.2.5, p. 43), the examples were restricted to use of Cabri. Hennessy et al. focus more broadly on teachers' implementation and use of ICT in teaching of school subjects like mathematics, English and science. My reading of Hennessy et al. (2005) contributed with ideas for my own study of teaching and teachers. This includes use of terms such as 'affordances' and 'constraints' (see Section 2.3.3), the outlining of aims for my research study, research questions and to have an emphasis on what teachers' considered as successful use of computer software.

2.2.7 Teachers' orchestration of computer software use

In recent years a number of French researchers, with Trouche as a key person but also with contributions from researchers outside France, have developed and utilised what Trouche (2005a) denotes as the instrumental approach to mathematics learning. This theoretical perspective emphasises the role of artefacts, such as computer software, in students' learning process with mathematics and particularly pays attention to the role of the teachers within the same learning process. Trouche and other researchers' contributions adopting this approach, like Drijvers, Gravemeijer, Haspekian, Monaghan and Ruthven, will be discussed as part of the elaboration of my theoretical framework in Chapter 3.

2.2.8 Teachers' use of dynamic geometry software (DGS)

Throughout the literature review in this chapter, I have referred to research papers considering teachers' implementation and use of:

- DGS such as Cabri;
- other kinds of ICT tools such as spreadsheets and calculators;
- new tools more in general

In this subsection I refer to some further contributions concerning DGS which emphasise *teachers' use of DGS* in mathematics teaching. In particular, I refer to discussions of DGS in two literature reviews in the area of DGS use in mathematics teaching, Hoyles and Noss (2003) and Laborde, Kynigos, Hollebrands, and Strässer (2006). Both overviews emphasise that there have been a large number of publications related to how *students* experience work with DGS. There has also been focus on the role of geometry represented in DGS. The difference between *drawings* and *constructions* with DGS, the role of the *dynamic dragging-function* to *check* conjectures and to *justify* and *investigate* a construction and the *difficulties* students' experience when working with a tool with unfamiliar 'constraints' are some of the things being emphasised in studies.

In a case study, situated within a two year research project in the United Kingdom, Hölzl (2001) makes a distinction in accordance with the two kinds of use of the dragging-function mentioned in the previous paragraph:

> A) drag mode as a test mode;
> B) drag mode as a search mode.
> In the first case, a construction is checked as to whether it has the desired properties; in the second case, new properties are recognised (Hölzl, 2001, p. 83).

Laborde (1993) points out how students usually do not consider geometrical properties of a figure, but emphasise production of a material *drawing looking visually correct*. This becomes a challenge for the teacher. She exemplifies with tangent line saying: "for the teacher the problem is not the production of the drawing of the tangent line but the determination of the point of tangency by means of geometrical relations" (p. 53). Ruthven, Hennessy, and Deaney (2005) argue that the typical use of DGS proposed by teachers in England is to let students *work with geometrical properties utilising the dynamic dragging-function*; further that many teachers in their teaching tried to *control* and *constrain* students' work in order to avoid students spending too much *time* on the exploratory affordances in the DGS. The time issue concerning implementation of DGS, is particularly addressed in the quoted paper by Assude (2005) in Section 2.2.4. The quoted papers in this paragraph all pay attention to teachers' vital role when DGS is used in teaching. This is also exemplified by Hoyles and Noss (2003) when they comment on the role of "appropriate teacher intervention" (p. 334) to support distinction between drawings and constructions with DGS. The term 'intervention' related to computer software teaching and the role of 'teachers interventions' are considered in Section 2.3.2.

I end this subsection by referring to a paper by Arcavi and Hadas (2000) where they list benefits of DGS, and also address the role of the teachers as guiding students' work with DGS in teaching. Arcavi and Hadas pay attention to the importance of teachers' role in utilising statements proposed in curricula, like the described requirements in the Norwegian curriculum in Section 2.1. They exemplify teachers' guiding role in teaching by listing four numbered points marked as (a) – (d):

> For example, the teacher
> (a) requests predictions which encourage students to take a stance on the problem and serve as a background against which to deal with unexpected results (e.g. "Predict when the area reaches its maximum", "Predict the form of the graph");
> (b) requests students to be explicit about the why (or why not) of what they see (e.g. "Why did the graph turn out to be not symmetrical");
> (c) helps to make explicit and to deal with intuitions or knowledge which may underlie an 'incorrect' prediction (e.g. "What would it mean for the graph to be symmetrical? Where would its maximum be?"),
> (d) leads the discussion, poses new questions, and promotes the coordination between different representations (Arcavi & Hadas, 2000, p. 42-43).

In Section 2.3, a number of terms are discussed describing the role of computer software in teaching and the role of teacher when computer software and in particular DGS are being used in teaching.

2.2.9 Summary of the literature review

Literature points to a lack or limited use of ICT tools in mathematics teaching compared to suggested demands from society and policy makers, such as are expressed in the Norwegian National Curricula L97 and LK06. The teacher is emphasised as having a crucial and difficult task, since implementation of ICT influences how mathematical objects are represented and handled, and challenges roles of students, teacher and the teachers' style of teaching. This provides a rationale for my research study emphasising the role of the teachers in implementation and orchestration of computer software use in teaching. I have emphasised how research literature has considered obstacles or issues for teachers' implementation of computer software in mathematics teaching. I have also referred to research emphasising a research design in which teachers talk about their teaching, and in particular their successful implementation and use of computer software such as DGS in mathematics teaching.

2.3 Terms applied in research with computer software

This section introduces a number of terms which are used throughout the thesis to describe the role of computer software in teaching. This section is a continuation of the literature review in Section 2.2 since I include references to literature applying the terms. Some of the terms, 'artefact', 'tool', 'signs' and 'orchestration' will be discussed further in Chapter 3 since they are key terms in my theoretical framework.

2.3.1 Artefacts, tools and signs

Fingers, sand, paper, ruler, compasses, abacus, calculator and computer software tools such as Cabri are examples of "things" that potentially can be helpful in learning and teaching of mathematics. I will use the term ‘artefact’ when I refer to such things, while I use the term ‘tool’ when I refer to students’ and teachers’ *use of* such artefacts. This way of distinguishing between a tool and an artefact is supported by Trouche (2004):

> When speaking of a tool before considering its users and its uses, I will speak of an *artifact* (Trouche, 2004, p. 282).

Looking historically, the whole existence and development of artefacts are closely linked to their development into and utilisation as helpful tools for their users; most artefacts have been developed based on humans needs for them as tools. In this sense the development of an artefact and its use as a tool goes alongside each other and cannot be separated. According to the Vygotskian tradition evolving from Marx and labour, a tool implies specific human activity; it is something you use and is designed to achieve something special. A concrete example is the hammer designed to serve as a tool for humans in activities. This view is supported by Säljö (2001) when he presents characteristics of an artefact:

> By artefacts we here consider measuring tools (weight, ruler), comb, computers, bicycle etc. Artefacts have been made to function as a tool for people when they solve problems, adapt information etc (Säljö, 2001, p. 31).[14]

Ongoing uses of artefacts have stimulated further development of the artefacts and how they are used by humans. Such *development* characteristics is emphasised by Leont'ev (1981a):

> Every object made by man – from a hand tool to the modern electronic computer – embodies mankind’s historical experience and at the same time also embodies the mental aptitudes moulded in this experience (Leont'ev, 1981a, p. 421).

Now I consider the development of *artefacts* used as *tools* in *mathematics teaching*. Many artefacts used in mathematics teaching, for example compasses, were not originally made to serve as tools to support students’ learning of mathematics but as a tool to use in practical activities. The same applies for many computer software tools, for example spreadsheets. Such tools have later been adapted for use in mathematics teaching. As a distinction, CAS and DGS (for example Cabri) were designed to serve as a tool to support students’ work with mathematics. Thus:

a) some artefacts have been adopted and developed further for use in mathematics teaching
b) some artefacts have been designed with the purpose of being used in teaching and to support learning

Research literature uses of the terms ‘artefacts’ and ‘tools’ are not distinct. In my own study I will restrict use of the term artefact and tool in accordance with the distinction pointed in the quotation by Trouche (2004) above. Monaghan (2007) makes a similar distinction and also argues that artefacts are *material*:

> An artefact is material. In the case of the calculator this is obvious – we can touch it. But, less obviously, algorithms that are created and used in mathematics

[14] The quotation from Säljö (2001) is translated to English by the author of the thesis

are material artefacts (Monaghan, 2007, p. 64).

Monaghan refers to the calculator as a material artefact, and in fact argues that algorithms are material too. He continues supplementing his argument above:

> The materiality of an algorithm is less immediate than the materiality of a calculator but it nevertheless exists in the materiality of its spoken or written form (without a sign form an algorithm cannot exist). The fact that any algorithm can be programmed into a computer attests to its materiality. To me, a tool is an artefact whose purpose is to perform a task or set of tasks; as an artefact, a tool is material (Monaghan, 2007, p. 64).

In the quotation above, Monaghan refers to the *sign* form of the artefact when being used, emphasising the written and spoken form of an algorithm. Similar to Monaghan's reference to calculator as a material artefact, I will refer to computer software, in particular Cabri, as a material artefact. Cabri serves as a material tool for its users, usually guided by some written handout as tasks and teaching packages concerning how to use Cabri and supported further by oral communication. Hence, oral and written forms of communication are examples of the sign forms which Monaghan refers to above. Vygotsky (1978) includes 'tools' besides 'signs' as being fundamental within cognition. More precisely, he argues that tools and signs *mediate*, with different orientation, between the person and the object of the activity. Mediation by the material artefact is considered as an *external tool for its users*, while mediation by for example language, writing and number system is what Vygotsky denotes as *internal oriented signs working as psychological tools for human action*. This difference is described in the quotation below:

> A most essential difference between sign and tool, and the basis for the real divergence of the two lines, is the different ways that they orient human behavior. The tool's function is to serve as the conductor of human influence on the object of activity; it is *externally* oriented; it must lead to changes in objects. It is a means by which human external activity is aimed at mastering, and triumphing over, nature. The sign, on the other hand, changes nothing in the object of a psychological operation. It is a means of internal activity aimed at mastering oneself; the sign is *internally* oriented (Vygotsky, 1978, p. 55).

The role of the object in activity and its relationship to the personal goals by its users is extensively discussed in Section 3.1. Schematically, based on Trouche (2004)'s distinction between artefact and tool, Vygotsky's tool and signs and the contribution by Monaghan, a relationship between these three terms may then be presented as in Figure 2.6:

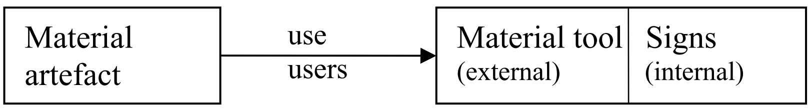


Figure 2.6: An artefact turns into a tool and involves signs for its users when using the artefact

However, the notion of signs is not only an internal matter, it also brings in a perspective on the relationship between the internal and external, between the "private" and the social and cultural impact signs have on tools and meanings. In other words, alongside the use of one or several material artefacts used as tools in the classroom, actions are mediated psychologically by their users through systems of signs[15] like oral and written words. Systems of signs, such as language or number systems, do not operate in a vacuum. Languages and number systems have been developed in order to have a communicative role in society; in teaching to influence others. Such considerations will be discussed in Chapter 3 as part of the elaboration of the theoretical framework.

2.3.2 Support, orchestration, teaching operation and intervention

Throughout the thesis I use the terms 'support' and 'orchestration'. Orchestration is also included in the title of the thesis and the research questions (see Section 1.3, p. 24). *Support* is in the thesis mainly used in four circumstances:

- Teachers (and sometimes students) supporting students' in their use of Cabri.
- Tasks and teaching packages supporting students' use of Cabri.
- Didacticians supporting teachers participating in the developmental projects.
- My analytical findings and claims often supported by findings in quoted research papers.

The three first kinds of circumstances refer to pedagogical support which I consider as empowerment or at least aimed to empower respectively students in their work with Cabri and teachers' implementation of Cabri. The two first circumstances refer to support which I in the thesis relate to *teachers' orchestration of Cabri-use* in mathematics teaching. Elaboration of the term 'orchestration' is in this thesis particularly inspired by two researchers, Kennewell and Trouche.

To simplify, when Kennewell (2001) talks about teachers' orchestration he includes pedagogical choices made by the teachers during the planning of lessons and decisions made during lessons and how they are accomplished in teaching. To use a teaching package guiding the work with computer software could be an example of a pedagogical choice made ahead of the teaching. Teachers' pointing with fingers on students' screens, and repeating and rephrasing of students' contributions in a plenary are examples of how teachers' orchestrations are accomplished in teaching with what I denote as *teaching operations*. Kennewell includes

[15] To indicate that signs often operate in a system, such as language, the term sign systems are often used instead of signs. But since signs is the term proposed in Vygotsky (1978, p. 55), I rather use signs throughout the thesis.

the different aspects of teachers' orchestrations in what he denotes as 'supporting features':

> The teacher's role is to orchestrate the supporting features – the visual cues, the prompts, the questions, the instructions, the demonstrations, the collaborations, the tools, the information sources available, and so forth… (Kennewell, 2001, p. 106)

This is similar to concerns suggested by Deaney, Ruthven, and Hennessy (2006) who argue for teachers' strategic role in orchestrating "fruitful learning opportunities, and support the development of effective data handling skills and techniques" (p. 16).

In my study with Cabri I am able to observe *teaching operations* and what teachers emphasise in their teaching through their instructions and questions, but also, indirectly, to observe choices made in their planning, such as use of textbooks and teaching packages, supporting the use of Cabri in teaching. Teachers' teaching operations relate to aids developed by the teachers to orchestrate students' learning. Such use of the term *teaching operation*, related to the teacher in teaching, seem to be included in what Fennema and Franke (1992) refer to as teacher's *pedagogical knowledge*. They argue that a teacher's pedagogical knowledge consists of knowledge and planning of teaching procedures, behaviour management and motivational techniques. The role of teaching operations will be considered further in Chapter 3 and in the analysis of teachers' orchestrations of Cabri-use in Chapter 6.

During teaching teachers might orchestrate when they interpret students' work with mathematics as seeming too easy or difficult. In my study, the scenario could be that a teacher orchestrates in a particular manner because the students did not succeed with their work with Cabri according to the teacher's expectations. In literature such kinds of orchestrations, where teachers somehow interrupts students' work, is often described by use of the term *intervention*, typically energised by a desire to make a change. Several researchers have analysed how teachers intervene when students use computer software, the nature of these interventions and how students experience these interventions.

Goos et al. (2003) suggest *four* kinds of emphases in teachers' interventions when orchestrating students' work in technology environments which I summarise below:

- Directing students to explore the tasks.
- Emphasising use of technology to discuss the solutions of a task.
- Holding back information and stimulating collaboration among students.
- Emphasising plenary presentations from groups of students followed by critical discussions.

I have already quoted Arcavi and Hadas (2000) who suggest a list with four points to describe teachers' *guiding* of students through their work with computer software in teaching (see Section 2.2.8, p. 46). I find this much related to the list by Goos et al. with a particular emphasis on the role of the teacher in posing questions during students' work. Goos et al. (2003) also discuss their four kinds of interventions according to *how technology is experienced* by the teacher:

1. Technology as master
2. Technology as servant
3. Technology as a partner
4. Technology as an extension of self.
   (Goos et al., 2003, p. 77-80)

According to Goos et al., a teacher who emphasises directing students initiates a transition of students from technology as a master to technology as an efficient servant. I would like to add that the *nature of the interventions* seems to be crucial: How explicitly does a teacher intervene into students' work if he/she aims to stimulate students to use Cabri as a construction tool and observes students' use of Cabri as a drawing tool? Thus, a teacher's intervention has to do with the kinds of changes intended by the teacher. Haspekian (2005) considers whether an intervention from a teacher has a positive, negative or negligible influence on students' learning. In the analysis in Chapter 6, I consider teachers' interventions related to their style of teaching and emphases in teaching where I utilise the terms 'affordances' and 'constraints'. These two terms are introduced in the next section.

The term orchestration is also included as a key term as part of 'instrumental orchestration' in the 'instrumental approach to mathematics learning' proposed by Trouche and constituting one of the theoretical perspectives outlined in Chapter 3. Trouche uses the term more specifically than for example Kennewell, emphasising instrumental orchestration as *didactical management of the artefact in a given environment*. For my study of teaching, the *teacher* has a crucial role in the didactical management where *Cabri* is the main artefact. The environment is the classrooms and computer labs with computer software and other equipment at schools in which teachers and students work. In my elaboration of framework in Chapter 3, I also consider the environment as being something bigger: the school and school system as part of Norwegian educational society. Trouche proposes specific processes involved when using artefacts such as Cabri in teaching and the instrumental orchestration of the use of this artefact. These processes and the suggested role of orchestration will be treated extensively in Chapter 3.

2.3.3 Constraints and affordances

In the previous section I quoted Kennewell who links teachers' orchestrations to supporting features. Orchestration of the 'affordances' and ‘constraints’ is according to Kennewell another key task for the teacher and Kerr (1996) points to how affordances and constraints can be identified with various software used in schools. But how are affordances and constraints related to my study of teachers’ orchestration of students’ work with Cabri? Gibson is an originator of the term affordances. In Gibson (1977) he defines affordances in the following way:

> I suggest that *the affordance of anything is a specific combination of the properties of its substance and its surface taken with reference to an animal* (Gibson, 1977, p. 67).

Gibson argues that affordances are closely connected to the environment and its nature. For example a stone that may have a surface that affords sitting on and the strawberry a substance that affords eating, while the toadstool has negative affordances on humans because it is poisonous. Although affordances usually are closely connected to the environment, it does not stop humans from influencing and elaborating affordances as argued by Gibson:

> The richest and most elaborate affordances of the environment are provided by other animals and, for us, other people (Gibson, 1977, p. 75).

This phrase from Gibson highlights the importance of human influence on environment. For my study this could be interpreted as teachers’ ways to emphasise affordances in Cabri. A key affordance given its users by Cabri is the dynamic dragging-function which affords its users the possibilities to investigate geometrical properties. However, this affordance only works well if the users have developed abilities to use the “Pointer” option in Cabri. This is a constraint of Cabri which students have to handle in order to utilise the dynamic dragging- function in their geometrical work such as to verify whether a construction has been successful. Another example of a constraint in Cabri is the following: If a circle is supposed to pass through a point in Cabri, the users need to move the mouse pointer close to the point until a text appears such as “Through this point”. This is a constraint in Cabri which students have to handle in order to make constructions in Cabri, and whether a student has been successful with the construction can be verified with the dynamic dragging-function.

Consequently, constraints in software such as Cabri could restrain or destroy students’ utilisation of affordances in the software and therefore students’ learning. This is a point where the role of teachers’ orchestrations could serve as crucial phrased in the following way by Kennewell:

> The role of the teacher is to orchestrate the affordances and constraints in the setting in order to maintain a gap between existing abilities and those needed to achieve the task outcome, a *learning gap* which is appropriate to the development of intended abilities (Kennewell, 2001, p. 107).

If students’ abilities to use Cabri prevent them from utilising affordances offered by the tool, the teacher might orchestrate the actions by an intervention constraining the use of software by showing in plenary how to use and utilise the affordances in software. Kennewell argues that teachers through their orchestrations can offer *structure for action* through constraining students' work with an affordance which only offers *potential for action*. Through constraining students' work with Cabri, the outcome could be that most students succeeded in handling the suggested tool use as a condition for utilisation of affordances in Cabri. Teachers' constraining of students' Cabri-use could for example be by decreasing or increasing the number of menu-choices students are allowed to use in Cabri, or by using a teaching package with a description of construction of 60 degree angles in Cabri.

Greeno (1994) argues that affordances can be interpreted as conditions in the *environment* which influence interaction and work as preconditions for activity. Moreover, he extends the discussion of affordances by arguing that affordances and abilities are closely connected and can be characterised as conditions for constraints:

> Affordances and abilities can be thought of as conditions in which the constraints of successful performance hold (Greeno, 1994, p.339).

Greeno also refers to attunement to constraints as a kind of experienced way of handling constraints, referring to an example with attunement of the steering wheel in order to handle the constraints of steering a car. A teacher might, in a given lesson, choose to *orchestrate by constraining students actions* to emphasise the attunement and develop abilities to *handle the affordances*. One way teacher might constrain could be to let the students utilise the dynamic dragging-function in Cabri by working with a pre-constructed figure in Cabri.

In this section (2.3.3) I have considered the terms 'affordances' and 'constraints' by looking back to key sources in the area (Gibson, 1977; Greeno, 1994), and how the terms can be used to analyse teachers' orchestrations in teaching (Kennewell, 2001). I argue that a careful analysis of teachers' handling of and emphases on affordances and constraints in computer software offers a way to characterise teachers' orchestrations of students' use of Cabri which I will utilise in analysis in this thesis.

2.4 Summary

The aim of this chapter has been to locate my research study of teachers' implementation and use of Cabri as a computer software tool in mathematics teaching within the educational context of Norwegian lower secondary schools. In Section 2.1 I referred to external requirements for use of ICT both in National Curricula and in developmental plans in Norway. This was followed up in Sections 2.2.1 and 2.2.2 where I indicated status quo for use of computer software in mathematics teaching in Norway seen in respect to these external requirements and the role of teachers' participation in a developmental project suggesting use of computer software. The literature review in Section 2.2 was by no means meant to cover the full variety of research concerning computer software in teaching. The literature review emphasises contributions from studies related to issues expressed and addressed by teachers in the implementation process and teachers' orchestration of, for them, a new tool which in my study was the computer software tool, Cabri.

When, in Section 2.3, I introduced some of the terms used in my thesis related to use of computer software, I included references to literature applying these terms. Hence summarised: Section 2.2 has a focus on literature which considers the three aspects to the left in Figure 2.7, while Section 2.3 sets out a list of terms to be used in the research (to the right in Figure 2.7):

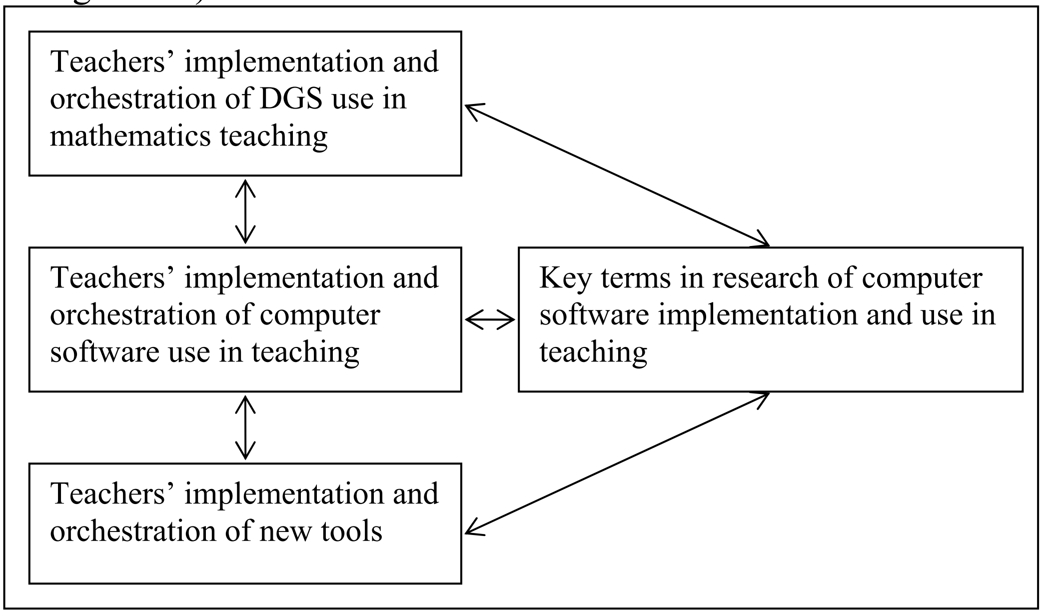


Figure 2.7: Four main aspects in the literature review in this chapter

A key point in this chapter is that it is not the computer software itself, the *material artefact*, which is my area of interest. Rather the focus is what characterises teachers' implementation and orchestration of computer software use and why. I have argued, supported by Trouche (2004) that from the moment we start to consider the users and use of an artefact in a teaching situation, it is helpful to make a distinction between the material artefact and the use of the material artefact as a tool for the user. In Section 2.3.1 also started to consider how use of material tools, like computer software, involves what Vygotsky refers to as psychological tools or 'signs'. In Chapter 3 I discuss how my two main theoretical perspectives address tools and signs. The term *orchestration* was in Section 2.3.2 elaborated as a broad term referring to teachers' planning and management in their teaching. In Section 3.2, I elaborate a different but complementing use of the expression *teachers' orchestration*.

In Sections 2.2.3 and 2.2.4 of the literature review I quoted Monaghan (2004). In the paper he utilises a model and approach by Saxe (1991) which Monaghan considers as "an activity theoretic approach" (p. 350) which share "commonalities with French work on instrumentation" (p.351). An activity theory approach is also used by Fitzsimons (2005) aiming to give contribution concerning considerations addressed in developing mathematics education with technology use. I apply activity theory and the instrumental approach as my two theoretical perspectives elaborated in the next chapter, sharing characteristics with the two-edged approach applied by Monaghan but not using the model by Saxe.

3 Theoretical framework and key notions

In Chapter 1, I introduced the setting of my research study within two developmental projects with didacticians and teachers, presented my aims for the research study and stated two research questions. In Chapter 2, I related the mathematical content in my study to requirements in National Curricula and plans in Norway concerning use of ICT tools in mathematics teaching. I indicated status quo for use of ICT tools in mathematics teaching and gave a review of research in my area of study. Nine terms: ‘artefact’, ‘tool’, ‘sign’, ‘support’, ‘orchestration’, ‘teaching operation’, ‘intervention’, ‘affordances’ and ‘constraints’ were introduced and related to my research study. This chapter will have a continued focus on these terms and others in relation to the theoretical perspectives I use later in my analysis of a case study emphasising three teachers’ initial implementation and orchestration of Cabri-use in mathematics teaching.

In the introduction to Chapter 2, I considered two of the main terms and concepts in my research, *implementation* and *use*. These two concepts are central in the analysis in Chapters 5 and 6. In Chapter 5 I analyse teachers’ implementation process of Cabri while Chapter 6 considers teachers’ orchestrations of *Cabri* use in teaching. These two different focuses, implementation and use in teaching, stimulated my decision to use two theoretical perspectives in my framework. In Section 3.1, I elaborate use of activity theory as a first theoretical perspective, while the instrumental approach to mathematics learning is elaborated as my second theoretical perspective in Section 3.2.

Activity theory is a socio-cultural perspective which emphasises the social and contextual character of learning. I utilise activity theory in the analysis of teachers’ *implementation* of Cabri, a new tool for the teachers and their students. I elaborate terms describing the process in which Cabri gradually was implemented and used in teaching. In the analysis in Chapter 6, the latter is considered as Cabri evolving into a ′cultural tool` for students and teachers through being used in teaching. My main use of activity theory is in the analysis in Chapter 5 where ′activity systems` has a crucial role. I argue that a classroom with students and teachers within a school can be seen as an activity system. In addition, I see teachers and didacticians as members of an activity system designed as part of the collaboration in the developmental projects. I will emphasise how different activity systems influence development of teaching and I introduce ‘intersecting activity systems` (Engeström, 2001) in the analysis. I also utilise Leont’ev’s distinction between collective activity and individual actions in my analysis. I interpret Leont’ev’s contribution to pay attention to the role of teachers’ *motives*, *goals* and *operations* when implementing and orchestrating Cabri-use in teaching.

The *instrumental approach to mathematics learning* emphasises how users of artefacts develop personal learning constructs in the environment where the use occurs. The theory offers the term 'instrumental orchestrations' which includes attention to *teachers' orchestrations* of students' work with computer software in teaching, in my study Cabri. This theoretical perspective is utilised in the analysis of teachers' orchestration of Cabri-use in Chapter 6.

In Section 3.3 I discuss concepts and how learning is accounted for within the two theoretical perspectives. I end the chapter with Section 3.4 where I consider possible epistemological controversies when utilising perspectives rooted within socio cultural and cognitive theories. In particular, I discuss how I see the two theoretical perspectives to *supplement* each other, and offer me as researcher different lenses to address my research questions. To simplify, I make the following distinctions regarding the two theoretical perspectives which I elaborate in this chapter and utilise in the analysis in Chapters 5 and 6:

- *Activity theory* guides the analysis of teachers' *motives* for implementation of Cabri.
- The analysis of teachers' *operations*, as part of their orchestrations of Cabri-use in teaching, is guided by utilising *the instrumental approach*.
- I argue that both perspectives contribute to the analysis of teachers' *goals* for use of Cabri in teaching.

3.1 Activity theory perspective on development

Section 3.1.1 includes a brief introduction to activity theory as a sociocultural perspective emphasising 'cultural tool' as an important term in my study of three teachers' Cabri-*use* in mathematics teaching. Within that section I also introduce 'subject', 'object' and 'mediating artefact' which are used as terms throughout this chapter. In Section 3.1.1 and throughout this section (3.1) I describe how activity theory contributes to analysis of teachers' *implementation* of Cabri. In Section 3.1.2, I emphasise contributions of Leont'ev (Leont'ev, 1978, 1981b) distinguishing between collective ´activity` and individual ´actions`. Leont'ev argues that in order to interpret humans' actions, we need to see them in relation to a social context of shared work activity. In Sections 3.1.3 - 3.1.6, I discuss what activity and activity system could mean in my research referring to the 'extended model of an activity system' (Engeström, 1999), 'intersecting activity systems' and the role of 'tensions' and 'contradictions' for development and changes in teaching (Engeström, 2001).

3.1.1 Development of cultural tools

In this section I briefly present characteristics of socio-cultural theories and give reasons why socio-cultural theories could be used in a study of teaching. I give an elaboration of ‘cultural tool’ where I indicate how a cultural tool gradually develops within a culture referring to my study of teachers’ orchestration of Cabri-use in teaching.

I have earlier mentioned the mediating role of *tools* and *signs* on the users of artefacts in teaching (see Figure 2.6, p. 48) giving the example with Cabri as a tool and teachers’ communication as a sign indicating this two-way relationship involved in mediation. Figure 3.1 visualises the dynamic process of initially bringing in a *new* mediating artefact, such as Cabri, and starting to *use* it in teaching. In Figure 3.1 and later in Figure 5.2, the role of the mediating artefact is illustrated linking the ‘subjects’ and ‘objects’. In my study of teaching, the users of the mediating artefacts are both teachers and students; teachers are referred to as the *subjects* of the activity while I consider students’ learning of topics in curriculum as *objects* in teaching. The artefacts allow the subjects to achieve the objects and thus the term *mediating artefact* has evolved:

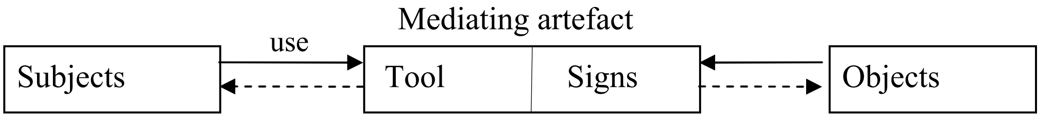


Figure 3.1: A “new” artefact is used initially in teaching

Lerman (2000) points to how material artefacts, when being used within a culture, mediate human actions. He uses the term ‘physical tool’ which I believe can be used interchangeably with Monaghan’s use of ‘material tool’ (see Section 2.3.1, p. 47). Lerman also suggests that a physical tool by being used in a culture becomes a *cultural tool*:

> The world and what things mean are mediated for us by others. Meanings signify, therefore, they are not identical with the empirical object, but are known only through language. By analogy with physical tools, cultural tools transform us internally because they form and transform the world and enable us to see and to act differently (Lerman, 2000, p. 57).

Consequently, ongoing use of an artefact in teaching impacts and gradually develops the culture and how things are experienced by students and teachers. The introduction of a DGS[16] package in teaching potentially stimulates changes in teaching. Use of the DGS artefact Cabri compared to use of compasses affects and changes the representations of geometrical objects and ways of operating on them, such as the affordances offered by the dynamic dragging-function in Cabri. Thus, I argue that students and teachers gradually develop a more established but still dy-

[16] DGS as an abbreviation for a dynamic geometry software package such as Cabri was introduced on page 32

namic way of using Cabri as a cultural tool illustrated in Figure 3.2:

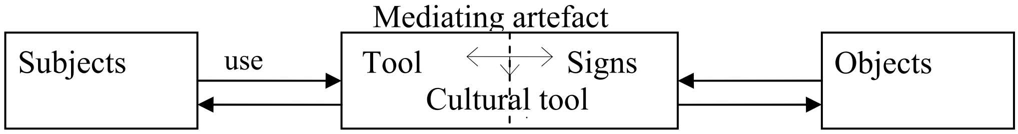


Figure 3.2: The evolution of a cultural tool

Compasses have developed as a cultural tool in mathematics teaching through their use over time. For teachers and students who have not met Cabri in teaching, Cabri is not yet such a cultural tool.

Compared to Figure 3.1, I have drawn a stippled line in Figure 3.2 between the tool and signs and unbroken arrows between the mediating artefact and objects. The users' cultural tool incorporates both the material tool and signs when using a mediating artefact representing objects within a culture. Although, according to Vygotsky, tools and signs are oriented differently, they mediate together when being used. Accompanying use of Cabri, teachers utilise other tools such as textbooks and different kinds of signs alongside the tools in teaching as already outlined (see Section 2.3.1, p. 48). Signs are observable in the way teachers speak and assist students during their work. I suggest that the development of Cabri as a cultural tool led to more transparent representations of mathematical concepts for the users indicated with the unbroken arrows on the right in Figure 3.2 compared to the stippled connection lines in Figure 3.1.

Since use of Cabri in teaching occurs within the school as an institution and culture, the term ´cultural tool` which evolved as a term in socio-cultural theories is also relevant for my study. *Activity theory* emphasises mediation of tool and systems of signs as crucial. This is highlighted in the quotation below:

> Activity theory proposes a strong notion of *mediation* – all human experience is shaped by the tools and sign systems we use (Nardi, 1996, p. 10).

Thus, to consider cultural tools is relevant for my research of Cabri-use in teaching where I utilise activity theory as a socio-cultural perspective.

In the coming subsections I elaborate my activity theory perspective on teachers' implementation of Cabri. I emphasise 'activity systems' as an aid to illuminate *issues* in teachers' *implementation* process which eventually led teachers to their Cabri-use in teaching. The role of *subjects* and *objects* within activity, which have been commented in this section (3.1.1), are considered more in depth in Sections 3.1.2 and 3.1.3.

3.1.2 Collective activity and individual actions

Vygotsky, Luria and Leont'ev are regarded as being pioneers in the early development of cultural-historical activity theory (Vygotsky, 1978; 1986) but with roots back to Marx and labour. Cultural historical activity theory, abbreviated *activity theory*, is a socio-cultural perspective. Cognition is explained in interpersonal and contextual dimensions as social activity emphasising the influential role the cultural, historical and institutional settings have on mind and thinking.

Although the contribution of Vygotsky was influential and regarded as the *first* generation of activity theory (Engeström, 2001), Leont'ev is often regarded as the "inventor" of activity theory (Säljö, 2001). However, Engeström (2001) refers to Leont'ev's contribution to activity theory as the *second* generation of activity theory, Vygotsky offering the *first*. What Leont'ev (1978, 1981b) did was to account for "the societal and collaborative nature" of actions (Engeström, 1999, p. 30) by considering the relationship between *individual action* and *collective activity* within the social and cultural context (Engeström, 2001). Thus, in order to interpret human action, one needs to see them in relation to a social context of shared work activity. Leont'ev argues that activity typically satisfies a *need* while actions are the *processes* by which activities are accomplished by humans. Consequently in my research, teaching is studied as actions by teachers and students within the activity in the systemic educational institution of school. In Section 3.1.4, this is considered as an *activity system*. I also argue that the developmental projects could be considered to have established an activity system consisting of didacticians and teachers in a *co-learning* (see Section 1.2, p. 21) partnership.

Leont'ev suggests different *levels* to account for activity. Below I refer to Kaptelinin (1996) who, like many other researchers, has described a three level model based on the contributions by Leont'ev:

> *Activities* are oriented to motives, that is, the objects that are impelling by themselves. Each motive is an object, material or ideal, that satisfies a need. *Actions* are the processes functionally subordinated to activities; they are directed at specific conscious goals. According to activity theory, the dissociation between objects that motivate human activity and the goals to which this activity is immediately directed is of fundamental significance. Actions are realized through *operations* that are determined by the actual conditions of activity (Kaptelinin, 1996, p. 108).

According to Jaworski and Goodchild (2006) the three levels can be summarised as:

> activity $\leftrightarrow$ motive; actions $\leftrightarrow$ goals; operations $\leftrightarrow$ conditions (Jaworski & Goodchild, 2006, p. 355).

I find the distinction in three levels helpful to illuminate teachers' *motives* for implementing Cabri and their *goals* energising their orchestration of Cabri-use in teaching. Motives and goals are included as terms in my Research Question 1 (see Section 1.3, p. 24). The *operation*-level is in my study about teachers' emphases in teaching such as on students' utilisation of affordances in Cabri. It also highlights how teachers accomplish their orchestrations of students' work in computer labs or in classrooms. Since teachers' operations are related to teaching, I use the term 'teaching operation' (introduced in Section 2.3.2, p. 49). Analysis of teachers' emphases in teaching and their teaching operations contribute to the illumination of characteristics in their orchestration of Cabri-use in teaching which are emphasised in Research Question 2.

I interpret the activity as superior to respectively actions and operations. From now on I will refer to the three levels, summarised with reference to Leont'ev, as the *upper* level, *second* level and *third* level.

The objects are, as emphasised by Kaptelinin in the quotation above, made by humans based on motives and embedded into an activity system as a driving force for the collective activity. In my frame, objects relate to activity in schools. The Norwegian society's requirements for teaching in schools provide the motives influencing the development of objects for teaching. Schools and teachers have been given responsibility to carry out and prepare students for their future "career" in society based on these official requirements. These requirements are in Norway primarily offered in the National Curriculum for different school subjects, such as mathematics, science, mother-language, each with different topics and themes to be handled in teaching. The role of *collective objects* are considered more in the coming section where I also emphasise that *objects* are personalised by students and teachers as *goals* in teaching. To summarise:

- The objects in mathematical teaching typically refer to students' work with mathematical topics represented in the mediating artefact such as students' work with geometrical constructions represented in Cabri.
- When considering Cabri in my research, *the objects are about teachers' implementation, orchestration of Cabri-use in teaching with students' learning of geometry related to requirements in the National Curriculum in Norway*.
- Accompanying the use of Cabri, teachers usually have some specific goals related to what they want their students to achieve when using Cabri in their work with geometry.

I consider Leont'ev's *upper level* to be central when I consider teachers' *implementation* of computer software, especially when analysing requirements brought through the National Curricula in Norway, L97[17] and LK06. Both curricula emphasise investigative and explorative use of computer software in mathematics teaching whenever appropriate and LK06 presents requirements for 'digital skills'. I now present an example from my study to exemplify *why* I consider this level being helpful in my analysis. I give an example from the mathematics part in the National

[17] The abbreviations L97 and LK06 were introduced in Table 2.1 on page 28

Curriculum at Grade 8 in Norway, where one of the main mathematics subject elements is as illustrated in Figure 3.3:

English version	**Norwegian version**
Pupils should have the opportunity to - examine, make, draw and construct figures using various tools and classify the figures according to their properties (Hagness & Veiteberg, 1999, p. 179)	*I opplæringen skal elevene* - undersøke lage, tegne og konstruere figurer med varierte redskaper og klassifisere figurer etter deres egenskaper (KUF, 1997, p. 167)

Figure 3.3: Statement in the National Curriculum L97

Based on such statements, having the role as motives for activity in schools, teachers, at least indirectly, formulate *objects* for teaching. The objects are also influenced by and influencing teachers' choice of mediating artefacts in teaching such as tasks and computer software tools, two kinds of mediating artefacts. In Section 2.2.2, I denoted statements in the National Curriculum as well as the requirements from the development projects as two kinds of *external* motives imposing *double innovation* on the teachers. The schools' and teachers' ways of handling and interpreting these external requirements, which I denote as *external motives,* for teaching in schools are considered in depth in the analysis of my study. In Sections 3.1.4, 3.1.5 and 3.1.6, I introduce and discuss how I utilise 'activity systems' in the analysis of teachers' motives for implementation of the computer software tool Cabri.

So far in this section I have explained that Leont'ev's upper level is evident during teachers' implementation of Cabri. In Table 3.1, I summarise this upper level and indicate how the second and third levels can be interpreted in respect to my research study. Later, in Chapters 5 and 6, I utilise these three levels in my analysis as evident from the bullet points in the introduction to this chapter (see page 58). In Section 4.7.4, I give an introduction to the analysis outlining how the different sources of data from my study contributed to the analysis in Chapters 5 and 6.

Table 3.1: Leont'ev's levels exemplified in my research study

Upper level: Activity and motives	The Norwegian society's requirements for teaching in the National Curriculum provide motives influencing the development of collective objects for teaching. Schools and didacticians in developmental projects also contribute with motives for activity in schools.
Second level: Actions and goals	A teacher's action could preparation of mathematical problems supposed to be solved by students. Teacher's orchestration of students' work is energised by his/her suggested goals in respect to the collective objects. I give an example from my study to pinpoint the difference between object and goal: - the object is about implementation and orchestration of Cabri-use in teaching with students' learning of geometry - the goals are what the teachers wanted to achieve with this object such as students' successful 'techniques' in Cabri (see Chapter 6) Thus, the objects related to motives based on requirements in the National Curricula are personalised by teachers (and students) as goals energising their actions in their teaching.
Third level: Operations and conditions	The teacher orchestrates Cabri-use for example by utilising a teaching package and having particular emphases in teaching. The operations during teaching are visible in teachers' style of teaching and by utilised teaching operations for example by pointing to the screen and taking possession of the computer mouse when the students try to utilise affordances in Cabri such as the dynamic dragging-function. Teaching occurs within conditions in schools, such as classrooms and computer labs, and influenced of decisions like grouping of students.

3.1.3 Key elements in activity systems

Activity theory proposes what I denote as *elements* in an activity system. Earlier in this chapter I have discussed the role of 'subject', 'object' and 'mediating artefact' in activity. I have referred to teaching within the educational institution of school as one example of an *activity system* (see p. 61). Motivated by their desires for the learning of their students, teachers utilise Cabri as a mediating artefact in mathematics teaching. In accordance with my claims in Section 3.1.1, teachers take the role of being subject in this activity system while students are part of the object in this activity system as exemplified in the bullet points on page 62. A well known model of actions in an activity system is presented in Figure 3.4 where subject, mediating artefact, object and 'outcomes' are included like in Engeström (1999, p. 30):

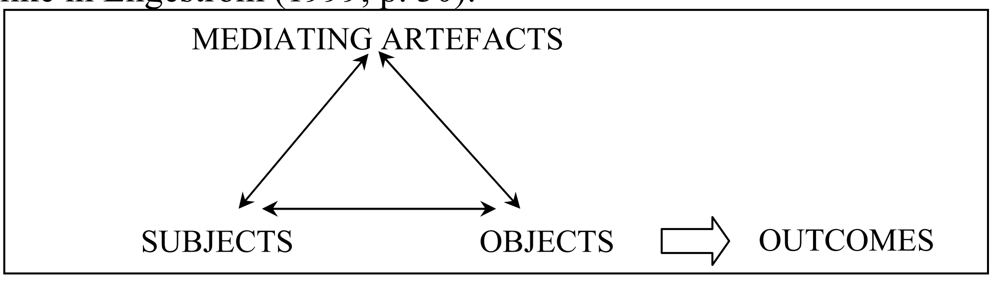


Figure 3.4: Based on Vygotsky's model of a complex mediated act

Outcomes are related to the whole activity system but particularly to the objects which they are achieved from. Outcomes of teaching and students' efforts are typically observed during lessons and formally evaluated in different kinds of tests. I argue that although outcomes *cannot* be made, teachers' *desired outcomes* during their implementation phase with Cabri energise teachers' efforts to expand motives into collective objects in an activity system and indicate their goals with this implementation. As an example, the desired outcomes teachers later wanted to observe and evaluate could be students' successful ability to construct perpendiculars, 60º and 90º angles. Teachers' goals also need to be seen in respect to actions and operations in teaching and achieved outcomes from teaching. The latter is considered in the analysis in Chapter 6 where I utilise the instrumental approach.

It is worth noticing that Vygotsky considered the triangular model, illustrated in Figure 3.4, to be a simple model of human action mediated by tools and signs (Vygotsky, 1978). The model did not distinguish between activity and action considered in Section 3.1.2. Engeström (2001) argues that the *second* generation of activity theory, building on contributions by Leont'ev (see Section 3.1.2), gives such an account of what influences mediation of actions. However, for Leont'ev the *subject* is an *individual* while Engeström refers to the subject as a *group*. Engeström has proposed an extended representation of activity systems building on the triangular model illustrated in Figure 3.4. In the extended representation, the three elements ´Division of labour`, ´Rules` and ´Community have been incorporated:

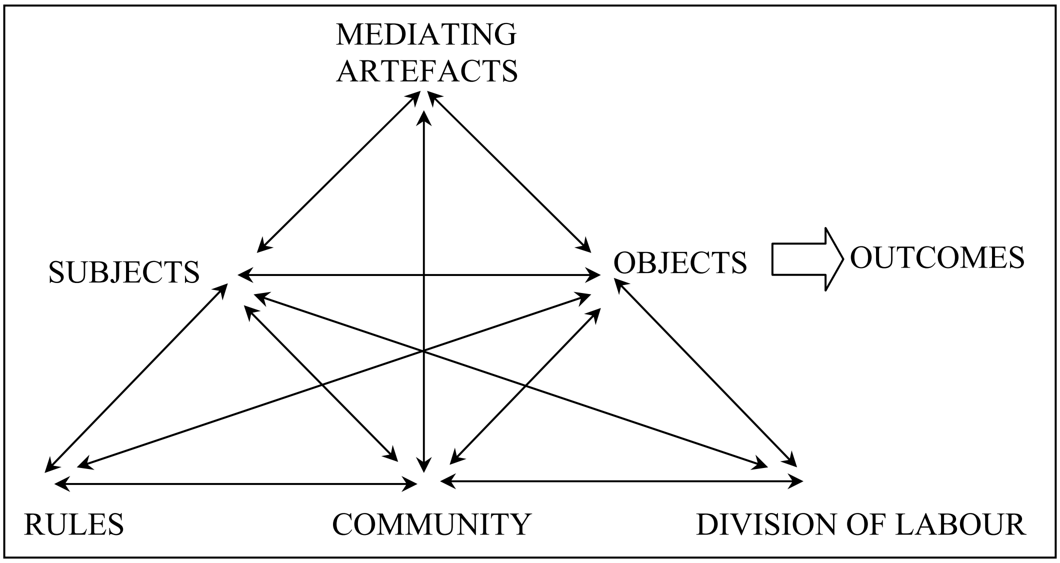


Figure 3.5: Model of Activity system based on Engeström (1999, p. 31) 'complex model of an activity system'

According to Cole, "the *community* refers to those who share the same general object" (Cole, 1996, p. 140-141). This is in teaching typically a teacher and the students although one could also add parents and politicians to the community. I suggest that difference in degrees of involvement and how general the objects are influence whether objects are shared or might be shared. I argue that to ensure a mathematically literate population is a general object for mathematics teachers while the earlier highlighted object related to Cabri:

> teachers' implementation, orchestration of Cabri-use in teaching with students' learning of geometry related to requirements in the curriculum in Norway

is a more explicit but initially not shared object since it originally was proposed by a few teachers involved in the developmental projects. Community is linked to subject and object respectively by ´rules` and ´division of labour`. Curriculum, textbook, constraints of time and common tests at each grade are examples of *rules* for the 'school activity system' and 'teaching activity systems'. *Division of labour* is typically organised in schools with school leaders, teachers and students in a power order.

3.1.4 Activity systems when considering implementation

In this section I argue why I utilise an extended representation of activity system (such as Figure 3.5). I elaborate three main activity systems which I consider in my research and consequences for development in teaching related to the teachers' involvement in more than one activity system. The three kinds of activity systems I consider are:

- The KUL activity system with teachers and didacticians in the two developmental projects.
- School activity system at each of the two schools in my study.
- Teachers' teaching activity systems with a main focus on three teachers at the two schools in my study.

I am aware that other activity systems and subjects could have been considered in a study of teaching, such as the role of parents, but this has not been the focus in my study and research questions.

When I observe teaching, for example in a computer lab, I enter into what I denote as a *teaching activity system* in Norway usually managed by one or sometimes two teachers with approximately 25 students. As indicated with the arrows in Figure 3.5, the teacher as the subject in this activity system could be seen to operate at *every* corner of the representation. The teachers decide both the *objects* and *mediating artefacts* for teaching but influenced by requirements in the Curriculum, school leaders and other teachers. Thus, both students' and the teacher's work are guided by the *same collective object*, but the object is addressed differently because of students and teacher's typically *dissimilar goals* related to their roles and interests in teaching sessions. Because of the responsibility given to teachers for teaching, both *rules* and *division of labour* are steered by the teacher in the teaching activity system but within the rules of the ‘collective school activity system’. If the teacher changes the rules for working, ultimately the division of labour will change to support these “new” rules. Obviously students’ rules are affected by youth culture, but in my study of teachers’ role in teaching it is teachers’ rules that dominate. Consequently, since the teacher “is there” for students and is in charge, I have defined students learning as part of teachers’ objects in the teaching activity system.

The participating teachers from each school are considered as being part of a *collective school activity system* where the community could be on the range from all the teachers and leaders at the school, all the teachers working at a grade, all the mathematics teachers at the school or at a grade, or only the few mathematics teachers participating in the developmental projects. The general staff meetings, in the staff room at the school, are examples of collective events in schools.

My third example of an activity system is the subgroup of teachers at schools who together with didacticians participated in the developmental projects guided by a number of objects and different goals. In this activity system, which I denote as the *KUL activity system*, I consider the teachers as the subjects who together with didacticians constitute the community. In Section 1.2 I pointed that the ICTML project was organised in collaboration with the bigger LCM project and shared similar theoretical grounding and goals as the LCM project. Some teachers (and didacticians) participated in both the projects while some only participated in one. Since these projects were so interwoven, I do not distinguish between an ICTML and LCM activity system, but rather consider this as one activity system, the KUL activity system.

The KUL activity system provoked intended actions for teachers in respectively the school activity system and each teacher’s *teaching activity system*. In each of these activity systems, the teachers are the subject and part of the community but potentially with different objects, rules, division of labour, mediating artefacts influencing teachers’ motives.

I end this section by sketching how activity systems is utilised in the analysis in my own study of implementation of Cabri. Implementation of Cabri and other kinds of computer software tools in mathematics teaching had been suggested by didacticians in the KUL activity system. However, implementation by the participating subgroup of teachers at a school potentially generated issues for teachers for example if a school wanted similar teaching in classes as evident with Austpark School in the analysis in Chapter 5. Such similar teaching indicates an established rule for shared objects within the collective school activity system at the school, and is evident as a ‘tension’ for the development of new shared objects which included implementation of Cabri.

3.1.5 Development of teaching through expansion

Engeström (2001) argues that activity theory could be summarised with reference to five principles. One of these principles emphasises the role of 'contradictions' and 'tensions' within and between activity systems potentially energising *changes* and *development* for human within and between activity systems:

> *The fourth principle* is the central role of contradictions as sources of change and development. Contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems (Engeström, 2001, p. 137).

Throughout the thesis, I use 'issue' as a term when describing potential problems and obstacles for teachers when they considered implementation of computer software in teaching, such as Cabri in my study. The reason why these problems or obstacles served as issues for the teachers was that they provoked a need for change or development in order to be solved. Engeström's use of 'tension' seems quite close to how I interpret this process which could be described as overt pulling in two directions. The tensions were related to teachers' desire to implement Cabri which made them consider a number of issues related to their and their colleagues more typical practice. When I later in the analysis discuss issues being raised by teachers, I consider potential *tensions* experienced by the teachers and relate the tensions to their role within and between *activity systems*. The emphasis on *contradictions* as "historically accumulating structural tensions" indicates that contradictions could be seen as provoked by repeatedly expressed tensions in activity systems. Contradictions in activity systems do not happen "over night" and are result of tensions typically experienced and brought up many times where teachers at last manage to change or develop their teaching. This strength of contradictions is expressed when Engeström refers to contradictions as a *driving force for change and development* when considering the processes they generate:

> …contradictions generate disturbances and conflicts, but also innovative attempts to change the activity (Engeström, 2001, p. 137).

At Austpark, mathematics teachers at the same grade had established rules to have similar mathematics teaching and to use the same tests at the same time. This is considered in depth in Chapter 5 where I refer to these as rules within their *school activity system*. At Austpark, some of the mathematics teachers at a grade wanted to implement Cabri which I consider as part of an object for their teaching activity system. In Chapter 5 I argue that these teachers' wanted implementation of Cabri generated a tension for the school activity system because of the rules with similar teaching and same tests. It became a tension since initially not all the mathematics teachers at the grade shared this object of implementing and later orchestration of students' learning of Cabri in teaching. If the teachers worked for a long time in order to achieve implementation of Cabri and convince colleagues to prioritise Cabri, these efforts could support and result in a contradiction energising *development* of this as a collective object in the school activity system and for each teacher's teaching activity system at the grade. The *development* could include design and use of Cabri-tests and similar approach to use of Cabri in accordance with their rules. The contradiction could also provoke *changes* in these rules, for example not to include testing of the outcome of Cabri-teaching. I suggest that teachers' efforts to address issues in order to overcome tensions indicate how important they consider the object and thus whether the tensions generate contradictions, changes and development in teaching.

Engeström (1987) explains use of the term 'expansion' when considering development for an activity system. He describes the development of an object, originally shared by a few persons in a community, which through a contradiction energises an expansion into a *shared object* in an activity system. Thus, use of the term *expansion* in activity systems refers to extended possibilities provided by peoples' efforts in the community. Later, in Section 3.3.2, consequences of extended possibilities through expansions are considered as *learning* for humans in activity systems.

Referring to the example considered above, the object concerning implementation of Cabri, originally only shared by a subgroup of mathematics teachers at a grade, developed into a shared object in every teacher's teaching activity system at the grade. This expansion of the object was made possible when the teachers considered issues and as indicated rules within their school activity system. Such consequences of expansions for the activity systems are highlighted by Hasu (2000):

> The expansion of the object eventually requires expansion in the rules, tools and division of labor – in the entire activity system (Hasu, 2000, p. 9).

I argue that tensions might be *externally* rooted, in my study related to the Government's statements concerning implementation of computer software in teaching. These statements work as a force for change in practice and development of new approaches to teaching. When some of the teachers at a school start to address tensions related to their more normal practice, which might not involve much use of ICT, new *internal* tensions could be brought up since the new object only is shared by some of the teachers in an activity system at a school.

Examples in this section highlight how a *tension* for an *object* of an activity system, embedded through motive in the National Curriculum, could lead to a contradiction generating development and changes in teaching. The object develops into a collective shared object in the school activity system through some teachers' efforts. In my analysis in

Chapter 5, interrelationships between activity systems will be described through use of ‘intersecting activity system’ representations with related comments (such as Figure 3.6, p. 71).

3.1.6 Illuminating tensions in intersecting activity systems

Earlier in the chapter I have referred to Engeström (2001) who discusses three generations of activity systems where Vygotsky and Leont’ev initiated respectively the first and second generation. Engeström proposes two *intersecting activity systems* as a minimal model for the *third generation* of activity system.

Why bother to introduce such a complex representation of activity systems? A benefit with the extended representation of an activity system (see Figure 3.5) is to emphasise the influence community, rules and division of labor have in activity systems. The teachers in my study gradually, as a subgroup of teachers at their schools, decided to implement Cabri for the first time in their teaching career. In order to be able to implement Cabri, teachers had to cope with tensions and address issues. Implementation of Cabri involved introduction of an artefact which they had not used before in teaching. In many classrooms in Norway, textbooks have evolved as a *cultural tool* with roles and aims in teaching, while implementation and use of Cabri provoked questions and issues related to the roles of students and teacher and how to proceed with the tool. Hence, I suggest that both rules and division of labour are more continually considered by teachers when a new tool is introduced than with more usual tools such as textbooks.

Engeström (2001, p. 136) illustrates *two intersecting activity systems* by placing two extended representations of activity systems (see Figure 3.5) next to each other. He omits outcome and introduce several objects at the intersection point between the two representations. In my analysis, I apply an elaborated version (see Figure 3.6) of Engeström’s representation of two intersecting activity systems to highlight different rules, communities, division of labour, mediating artefacts and outcomes as well as different objects which is most visible in Engeström’s representation. I try to highlight how the *KUL activity system* proposed actions for the *teaching activity systems* but then indirectly for *the school activity system* because of the teaching activity systems’ relation to school activity systems. In Figure 3.6, I present an example concerning proposed implementation of computer software in teacher’s teaching activity systems. In the figure, the text in red, placed above each of the seven elements (subject, rules etc) in the activity system representation, points to the KUL activity system. The blue text, placed below each of the element, points to how didacticians proposed activity and actions for each teacher’s teaching activity system based on aims in the developmental projects.

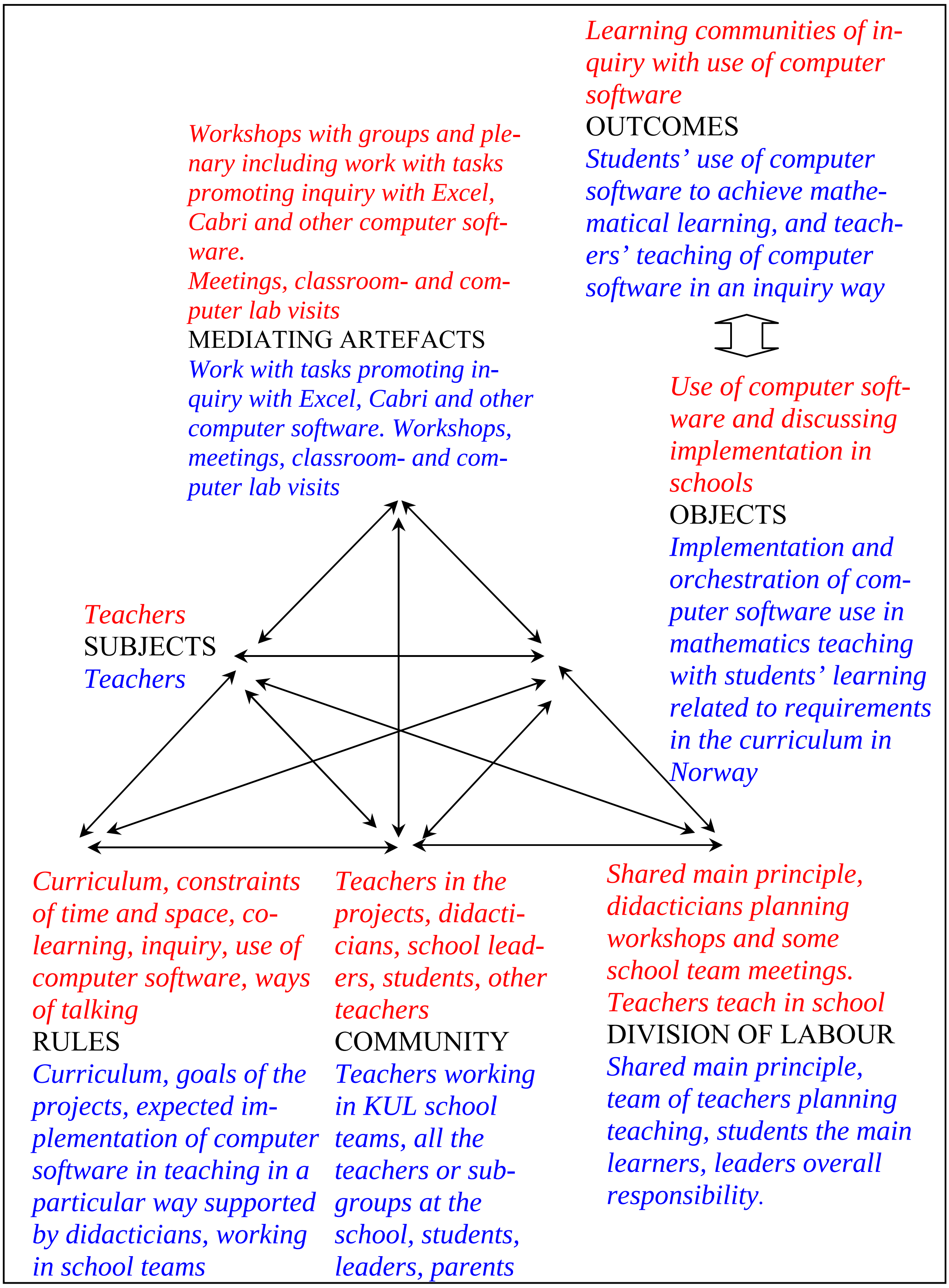


Figure 3.6: The KUL activity system and proposed actions for teaching- and school activity systems

In the analysis in Chapter 5, I argue that didacticians in the developmental projects supported teachers' development of objects by proposing motives for the activity in schools such as students' learning of geometry utilising Cabri and inquiry. The analysis in Chapter 5 also indicates that didacticians' and teachers' *desired outcomes* (introduced in Section 3.1.3, p. 65) influenced the objects and other elements in the activity systems, and explains why the arrow between objects and outcomes is two-edged and not one-edged as illustrated in Figure 3.5. I want to highlight that this support from didacticians served as a tension for teachers since outcomes in an activity system happen and are achieved from objects; outcomes cannot be made. This is commented further in Chapter 5. In Chapter 5, I present similar representations (see Figures 5.1 – 5.3) as Figure 3.6 based on analysis of teachers' implementation of Cabri. Issues within each element are indicated with bold text in the figures.

I argued in the previous paragraph that the KUL activity system indirectly proposed actions for teachers in school activity systems because of the teaching activity systems relation to school activity systems. This was also highlighted in Section 3.1.5 concerning rules for teaching as a shared object at one school in my study. When didacticians supported teachers' implementation of computer software in teaching, several of the teachers in the projects needed to convince colleagues to do the same because of the rule with similar teaching in their school activity system. Thus, if a teacher in the projects wanted to implement a computer software tool in teaching, it might generate tensions within his/her school activity system and issues needed to be addressed.

In this chapter I have so far considered potentials offered by activity theory as a socio cultural perspective on teaching, in particular teachers' implementation of something "new" in teaching. I have considered the role and development of *cultural tools* that mediate human actions within activity. I have paid attention to the contribution of Leont'ev as vital for the development of activity theory and a three level distinction which have been made based on his contributions (see Section 3.1.2, p. 61). Furthermore, I have discussed elements in the extended model of activity systems (Engeström, 1999) and in particular intersecting activity systems (Engeström, 2001). In the analysis in Chapter 5, I utilise intersecting activity systems when considering the role of issues, tensions and contradictions for change and development of teaching (Engeström, 2001). Thus, the unit of analysis in my research of teachers' implementation of Cabri, needs to account for the role of teaching within activity or the *activity systems*:

> The solution offered by activity theory is that a minimal meaningful context for individual actions must be included in the basic unit of analysis. This unit is called an activity (Kuuti, 1996, p. 26).

This quotation from Kuuti highlights the importance of analysing an individual's actions as part of the different occurring communities which is exactly what I do in Chapter 5. In Section 3.2, I will argue that the ´instrumental approach` also contributes to the unit of analysis when analysing teachers' orchestration of Cabri-use in teaching.

3.2 The instrumental approach perspective on teaching

The instrumental approach to mathematics learning (Trouche, 2003; 2005a) is a theoretical perspective which after this is referred to as the *instrumental approach* and utilised together with activity theory as my theoretical perspectives. The instrumental approach is a transposition to mathematics of what I denote as the *general theory of instrumentation*. This general theory is elaborated in contributions by Rabardel such as Vérillon and Rabardel (1995) and Rabardel (2002) suggesting that humans' develop 'instruments' when using artefacts. Trouche has adapted the general theory to mathematics and gives special attention to teachers' orchestrations of students' development of instruments denoted 'instrumental orchestration' (Trouche, 2004).

This section (3.2) is composed of three subsections. Section 3.2.1 contains elaboration of the term instrument and two suggested processes involved in humans' development of instruments. In Sections 3.2.2 and 3.2.3, teachers' orchestrations of students' development of instruments, teachers' instrumental orchestrations, are considered and related to my research. In this chapter I argue that the instrumental approach is helpful when analysing mathematics teaching with computer software, and is later utilised in the analysis of teachers' orchestration of Cabri-use in teaching (see Chapter 6).

3.2.1 The term instrument and development of instruments

The term 'instrument' has a specific signification in the instrumental approach (and the general theory of instrumentation). An instrument is defined by Vérillon and Rabardel (1995) as a personal 'psychological construct'(see Section 3.3.1) which a human, the subject, develops when he/she uses an artefact. The development of instruments is illustrated in Figure 3.7:

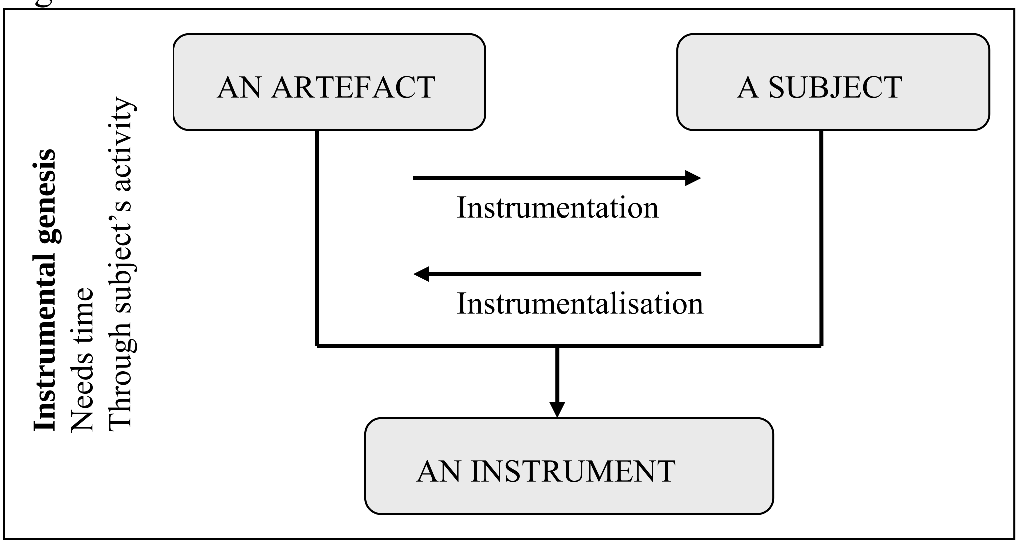


Figure 3.7: Based on Trouche (2005a, p. 144) "From artifact to instrument"

The development of an instrument is denoted *instrumental genesis* and as illustrated above composed of *two dialectically related processes*, 'instrumentation' and 'instrumentalisation'. These two processes are characterised in the following way by Haspekian (2005) referring to respectively instrumentalisation and instrumentation:

> Thus, the idea of instrumental genesis reflects the fact that using a tool is not a one-way process, there is dialectic between the subject acting on his/her personal instrument and instrument acting on the subject's thinking (Haspekian, 2005, p. 118).

These two processes are elaborated further in Section 3.2.3 when I consider how teachers' orchestration of Cabri-use in teaching can be related to support of these processes. Simplified, in relation to my study, I interpret *instrumentation* (illustrated in Figure 3.7) to be about getting to know what Cabri affords, how Cabri represents mathematical concepts and properties and development of abilities to use the tool. *Instrumentalisation* is about utilising and investigating in different ways the affordances offered by Cabri. I consider my interpretation of the processes to be similar to Kaptelinin (2003, p. 834) who refers to instrumentation as "developing an ability to apply the tool in order to carry out meaningful tasks", and instrumentalisation as "development and modification of a tool by users themselves".

In Figure 3.4 (see p. 64), I illustrated what is known as Vygotsky's model of a *complex mediated act* including *subject*, *mediating artefact* and *object*. In the different activity systems related to my research considered in Section 3.1, I interpreted teachers to be the subjects and Cabri being the main mediating artefact. Implementation and use of Cabri in teaching and students' learning of Cabri and geometry were argued to be the objects of this activity. In this section I have introduced the instrumental approach and subjects' development of *instruments* when using artefacts, such as Cabri, in teaching illustrated with Figure 3.7. Compared to activity theory and related to my research study, when utilising the instrumental approach Cabri is still the main artefact while I consider students to be the subjects not the teachers although I am considering teaching and teachers' role. Teachers' role is instead seen as an orchestrator of students' development of instruments (see Section 3.2.2).

Object is used with a *different* meaning in the instrumental approach compared to its role in activity theory described above. An artefact such as Cabri affords representation of geometrical concepts and properties which by researchers utilising the instrumental approach and the general theory of instrumentation are referred to as objects. Haspekian (2005) exemplifies by references to cell-variables and cell-formulas in spreadsheets. A spreadsheet formula such as =A5*2 is by Haspekian denoted as an example of an algebraic *object* afforded in spreadsheets.

Below, in Table 3.2, I summarise how I consider the two theoretical perspectives' use of the terms subject, mediating artefact and object, and how teachers' role is addressed.

Table 3.2: Terms utilised within the two theoretical perspectives

	Activity theory	The instrumental approach
Subject	Teachers	Students
Mediating artefact	Cabri	Cabri
Object	The object is collective and the "driving force" for the community in an activity system. In my study: Implementation and use of Cabri in teaching and students' learning of Cabri and geometry	Object is used more "loosely" than in activity theory. Related to my research, object is used when referring to representations of geometrical concepts and properties afforded by Cabri.
Key terms related to use of artefacts	Tools, signs and cultural tools	Tools, signs and instruments
Teachers' role	The subject in activity systems related to teaching	Orchestrating students' development of instruments (instrumental genesis) when using artefacts in mathematics teaching

The existence of artefacts and tools are obvious because of their materiality, and signs such as language because of its communication importance, while *instruments* and *cultural tools* are more compound constructs. In Section 3.3 I offer a comparison between cultural tools and instruments, proposed as concepts in the two theoretical perspectives, and how they contribute as theoretical terms in my analysis.

Although I consider both the teachers and their students experiencing instrumental genesis when using artefacts, my *main* focus is on teachers' orchestration of *students'* instrumental genesis. In the final two subsections of this section (3.2), I consider how the term 'instrumental orchestration' is used to account for the role of the teacher in assisting students' instrumental genesis which was illustrated in Figure 3.7. In Section 3.2.2, I outline the term 'instrumental orchestration' and what I include when I later analyse teachers' orchestrations of Cabri-use. Section 3.2.3 contains classifications of teachers' instrumental orchestration and how the orchestration relates to instrumental genesis.

3.2.2 Instrumental orchestration

Teachers' vital role in supporting students' instrumental genesis is in Trouche (2003) characterised by introducing the term 'instrumental orchestration':

> We will call *instrumental orchestrations* the various *devices* that a teacher organizes, with an aim of *assisting* the *instrumental geneses* of students (Trouche, 2003, p. 792).

By ‘devices’ Trouche refers to design of technical solutions supporting orchestration of teaching, like a projector screen affording possibility to present use of software and support students’ instrumental genesis at a computer lab. Trouche relates instrumental orchestrations to teachers’ ways of supporting their students in the accomplishment of tasks, and organising the *learning environment* when computer software is used in teaching. Organising learning environment is about working conditions in teaching such as grouping of students and use of supporting teaching packages.

In Section 2.3.2, I elaborated the term ‘orchestration’ with references to a contribution by Kennewell. Both Trouche and Kennewell use the term orchestration related to teachers. The main point of difference is that Trouche theoretically relates these orchestrations to students’ instrumental genesis. Below I briefly indicate how this “double use” of the expression ‘teachers’ orchestration’ is coped with in the analysis chapter.

In Sections 6.1 and 6.2, I argue that teachers’ *arrangements*, *emphases* and the nature of teachers’ orchestrations, where I emphasise the role of *teaching operations* and their *style of teaching* in Cabri-lessons, are part of teachers’ orchestration of Cabri-use. There I also argue that teachers’ orchestrations, together with their expressed comments to the teaching, are influenced by teachers’ *goals* for Cabri-teaching. In Section 6.3, I utilise the instrumental approach to analyse teachers’ orchestrations of students’ instrumental genesis related to the *instrumentation* and *instrumentalisation* processes (see Figure 3.7). In my writings, I use the expression *teachers’ instrumental orchestration* in Section 6.3 to distinguish teachers’ orchestration of students’ instrumental genesis from the broader use of teachers’ orchestration discussed in Sections 6.1 and 6.2.

3.2.3 Classifying teachers’ instrumental orchestration

In this section I elaborate further teachers’ instrumental orchestration of Cabri-use in teaching. First I introduce ‘technique’ as a term when considering teachers’ orchestrations and I comment on my use of ‘teaching operations’ introduced in Section 2.3 and used in my description above. The main part of this section is a revisit of the instrumentation and instrumentalisation processes introduced in Section 3.2.1. In particular, I relate and characterise teachers’ orchestration of Cabri-use to these two processes building on contributions by Trouche. I also consider *objectives* and *levels* of instrumental orchestrations. I end this section (3.2.3) with a summary where I raise some critical considerations on the term instrumental orchestration.

Techniques and teaching operations

Throughout the thesis, I use the term 'teaching operation' to describe teachers' behaviour when assisting students' with their use of Cabri. In Section 2.3.2 (see p. 49) I gave the following examples of teaching operations:

> Teachers' pointing with fingers on students' screens, and repeating and rephrasing of students' contributions in a plenary are examples of how teachers' orchestrations are accomplished in teaching with what I denote as *teaching operations*.

Trouche refers to 'gestures' which he elaborates as observable behaviours and relates to 'schemes'. Scheme as a term within the instrumental approach is considered in Section 3.3.1. Here I briefly refer to Touche's elaboration of gestures:

> We shall call gesture a student's elementary behavior that may be observed, component of a scheme (Trouche, 2003, p. 789).

I consider teaching operations to be one kind of observable gesture utilised by teachers in teaching. In my analysis of teachers' orchestration of Cabri-use (see Chapter 6), I characterise teachers' emphasis in teaching on how to succeed with the tool, such as drawing of a circle with centre on a line and the circumference through a given point, as emphasis on *successful technique* with Cabri. Analytical findings in Chapter 6 indicate that two of the teachers in my study several times talked about *accurate* use of Cabri. This emphasis is considered to be concern for students' successful techniques with Cabri. Such visible techniques related to use of an artefact like Cabri, are by Drijvers and Gravemeijer (2005) denoted 'instrumented techniques' with reference to Lagrange. In fact, such instrumented techniques are argued to be "the gateway to the analysis of instrumental genesis" (Drijvers & Gravemeijer, 2005, p. 169).

When commenting on Trouche's use of the term 'gestures', Monaghan (2007) describes instruments as "sets of gestures realized in the execution of a task on an instrument" (p. 65). Thus, I argue that my use of both *techniques* and *teaching operations* relate to Trouche's use of *gestures* when considering teachers' instrumental orchestrations. However, since gestures have a much broader use and explicitly are related to schemes, I will not use the term gestures in my research.

Orchestrations of the instrumentation and instrumentalisation processes

As illustrated in Figure 3.7 (see p. 73), the *instrumentation* process is directed from the artefact towards the users. For my study this means that the world of Cabri is offered the students. With DGS such as Cabri, geometrical figures, constructions and the system of relations between them are in focus. The *dynamic dragging-function* in Cabri affords its users the possibility to investigate the point of intersection of angle bisectors for different kinds of triangles and other polygons. In the next paragraph, I consider utilisation of this and other affordances in Cabri as related to the instrumentalisation process. However, students' utilisations of affordances are also affected by their *instrumentation* process. In order to utilise affordances, students have to be *aware of* the dragging-function's existence and *developed techniques* to use the *mouse pointer* in Cabri successfully which I consider being related to the instrumentation process. *Measuring* and *calculating* are other kinds of affordances offered in Cabri beside many others including more advanced affordances like animations and macros. Two *constraints* (see Section 2.3.3) in Cabri that users have to deal with are the *menu system* and development of *techniques in* Cabri in order to be able to utilise affordances in Cabri.

A *teacher* might in the teaching stimulate students' instrumentation processes by using a teaching package that puts attention to techniques, affordances and constraints offered by the software as well as by his/her emphases in teaching. The *instrumentalisation* process is directed from the users toward the artefact: Users of Cabri take control of the tool. I consider teachers' emphasis on supporting students' *investigative* and *collaborative* efforts with the tool and to emphasise students' *utilisation* for example the dragging-function in Cabri to check and verify constructions made as orchestration of the instrumentalisation process.

Trouche (2005a) argues for instrumentalisation as a process with *stages,* and he exemplifies in a setting where the artefact is a symbolic calculator. He identifies three stages in the instrumentalisation process:

> The instrumentalization process, directed by the subject, involves several stages: a stage of *discovery* and *selection* of the relevant keys, a stage of *personalization* (one fits the tool to one's hand) and a stage of *transformation* of the tool, sometimes in directions unplanned by the designer… (Trouche, 2005a, p. 148)

Below I briefly outline each of the stages and suggest *how* teachers' could orchestrate students at each of the stages. In the later analysis in Chapter 6, I consider to which extent teachers' orchestrations of Cabri-use in my research study could be related to these three suggested stages in the instrumentalisation process.

I relate Trouche's "discovery and selection"-stage to students' utilisation of affordances with some basis in awareness of *affordances'* existence, such as the dragging-function, and *developed techniques*. This stage of the instrumentalisation process could be supported by teachers in their orchestrations when they emphasise utilisation of Cabri to check and verify constructions made. Trouche's "personalisation of the tool"-stage is evident when students utilise Cabri with *personal adopted techniques*. A teacher who challenges the students to investigate Cabri and share their achievements with each other potentially supports students' development of such personalised techniques. One example of such a technique could be students' marking of angles in Cabri in a triangle based on three points not all being the three corners which is the conventional technique with triangles in Cabri. I consider Trouche's "transformation of the tool"-stage to be related to modification and enrichment of Cabri when students work *investigatively and openly*. Teachers' orchestrations of this stage could be to let students work freely with the tool and to challenge them to try using the tool in different ways.

Trouche (2004) also introduces the term 'objectives' of teachers' instrumental orchestrations and distinguishes between teachers' *main* and *secondary objectives* of such orchestrations. The *main* objective originates "from the necessity of orchestration itself" (Trouche, 2004, p. 296), for example, when several students have problems in accomplishing as task with Cabri. The *secondary* objectives relate more to what the teacher wants to achieve with the orchestrations, for example in favouring debates and making explicit procedures as exemplified in (Trouche, 2004, p. 300).

To summarise, within this section (3.2) I have emphasised how the instrumental approach offers concepts for analysis of mathematics *teaching* with computer software. I have argued that attention to teachers' instrumental orchestration gives the researcher tools to analyse teachers' role during students' use of Cabri in mathematics teaching. In the instrumental approach, the latter is seen as support of students' instrumental genesis with Cabri composed of instrumentation and instrumentalisation processes. As explicitly claimed by Haspekian (see the quotation presented in Section 3.2.1, p. 74) and indicated with the arrows in Figure 3.7, the *dialectic* between the processes is crucial and exemplified in the previous subsections with affordances and utilisation of affordances.

3.3 A framework with two theoretical perspectives

This section of the theory chapter discusses how the two theoretical perspectives, *activity theory* and *the instrumental approach*, support me as a researcher with analytical tools to analyse three teachers' implementation and orchestration of Cabri-use in mathematics teaching. In Chapter 2, I outlined that this thesis considers *implementation* of Cabri as a developmental process where teachers' orchestration of Cabri-*use* in teaching is the endpoint of teachers' initial implementation of Cabri (see p. 27):

> I analyse the process of development in teaching from teachers' first introduction to Cabri in workshops at UiA where they started to discuss possible use and what they wanted to achieve with use of Cabri in teaching. In follow up workshops and in school team meetings, the teachers started to address *issues* they needed to overcome in order to have a successful use of Cabri in teaching. Thus, implementation of Cabri was a process leading up to the three teachers' orchestration of Cabri-use in mathematics teaching, but implementation and use do indeed also overlap.

In particular, I emphasise how the *two* theoretical perspectives supplement each other contributing with different focuses to analysis guided by the two research questions (see Section 1.3, p. 24). In the introduction to this chapter I gave the following simplified distinction (see p. 58):

- *Activity theory* guides the analysis of teachers' *motives* for implementation of Cabri.
- The analysis of teachers' *operations*, as part of their orchestrations of Cabri-use in teaching, is guided by utilising *the instrumental approach*.
- I argue that both perspectives contribute to the analysis of teachers' *goals* for use of Cabri in teaching.

In Section 3.2.1, I argued that the focuses on the teacher and on mathematics teaching with Cabri are addressed differently within the two theoretical perspectives which was summarised in Table 3.2 (see p. 75). This section (3.3) contains two subsections. In Section 3.3.1, I consider possible relationships or not between instruments and cultural tools as terms within the two theoretical perspectives. Section 3.3.2 discusses how learning is considered within the two perspectives. Section 3.4 summarises how the perspectives contribute to research of mathematics teaching with computer software and possible controversies raised when utilising perspectives with different theoretical roots in a theoretical framework.

3.3.1 Development of instruments versus cultural tools

Both of my theoretical perspectives claim to build on Vygotsky's contributions emphasising the mediating role of *tools* and *signs* when human use artefacts. The interplay between tools and signs through ongoing use of artefacts are outlined differently:

- Figure 3.2 (see p. 60) illustrates the evolution of *cultural tools* proposed in socio-cultural theories including activity theory.
- Figure 3.7 (see p. 73) illustrates the development of *instruments* proposed in the general theory of instrumentation and utilised in the instrumental approach.

Activity theory emphasises the influence of the collective object on the use of mediating artefacts as tools within activity systems. In my elaboration of *teaching activity systems* (see Section 3.1.4, p. 66), I argued that I consider the teacher as the *subject* whose actions are directed to the *object* of students' learning of mathematical topics in the National Curriculum. In an activity system, an object is collective in the sense that it is shared by the community which typically in teaching involves one or several teacher(s) and students. However, teachers and students obviously have different kinds of goals according to different roles in teaching. Uses of tools are influenced by the social and cultural use of signs, such as language. This implies that new tools for a culture, such as Cabri in my research, evolve as *cultural tools* (see Section 3.1.1) within the culture. Use of a cultural tool also shapes its users' social and psychological processes, and it is therefore vital for learning that the users develop appropriate cultural tools. Säljö (2001) describes such a process when suggesting that knowledge, which exists in interaction between humans, gradually becomes part of each human's actions and thinking and is tied into artefacts in the culture evolving as cultural tools.

The *instrumental approach* describes how students through their use of an artefact gradually develop the artefact into personal mediating instruments supported by the environment where the teacher has a vital role. Instrumentalisation and instrumentation are the key processes in this mediation; instrumentation operating from the artefact to the users, and instrumentalisation in the opposite direction. Mediation is often associated with socio cultural theories, but it is evident from Rabardel's elaborations that *mediation* is also a key term in the general theory of instrumentation. Rabardel claims that the instrument is a mediator between *subject* and *object*. In Section 3.2 I argued that students as users of artefacts are the subjects within this theoretical perspective. Objects are used differently than in activity theory as I have described in the following way (see Section 3.2.1, p. 74):

> An artefact such as Cabri affords representation of geometrical concepts and properties which researchers utilising the instrumental approach and the general theory of instrumentation refer to as objects.

Rabardel also distinguishes between epistemic mediation' and 'pragmatic mediation'. Epistemic mediation works from object to subject where the instrument is defined as "a means allowing knowledge of the object", while pragmatic mediation is from subject to object where the instrument is defined as "a means of a transforming action (in a broad sense including control and regulation) directed toward the object" (Rabardel, 2002, p. 63). Actually, this description seems close to what Wells (2002) argues when referring to work within activity theory. He distinguishes between mediation offered by tools and signs according to how mediation mainly is oriented and its nature: Subject-oriented interaction and object-oriented action.

Comments so far in this section indicate similarities for instruments and cultural tools in that they address mediation of tools and signs as the basis of human' use of artefacts. An important *distinction* between the two theoretical perspectives is how *learning* is accounted for and related to instruments, cultural tools and expansions in activity systems.

3.3.2 Learning within the two theoretical perspectives

Learning theories mainly address learning. However, since the purpose of teaching is to enable students' learning and teachers are learners in a developmental process (Jaworski, 2007), learning theories are certainly relevant when researching development in teaching.

In activity theory, learning is related to development and changes in activity systems. The concept *expansion* is used to describe the process in which objects become shared with consequences and new opportunities for the whole activity system as emphasised in Section 3.1.5. Roth and Lee consider how activity theory accounts for the relationship between learning and development:

> CHAT has much potential for educators, because it is thoroughly about development and learning, encompassing the system as a whole and various subjects and communities that constitute it (Roth & Lee, 2007, p. 204).

With references to a number of researchers Roth and Lee conclude that activity theory addresses successfully the relationship between individual and collective learning:

> Two manifestations of expansive learning arise from this interplay between individual and society. On one hand, learning is expansive when it contributes to an enlarged room to maneuver for the individual whereby new learning possibilities are formed. On the other hand, learning is also mediated by the division of labor in collaboration, which inherently leads to learning outcomes and forms of societal activity (Roth & Lee, 2007, p. 205).

Thus, when analysis indicate tensions leading to contradictions and expansions for activity systems, learning takes place since humans within the community are able to consider and benefit from new opportunities. In socio-cultural theories, the distinction between social and individual when considering learning are *also* accounted for when studying the role of *cultural tools*. Evolution of cultural tools have been outlined earlier in the chapter and discussed in the previous section with reference to learning. There I argued that cultural tools "shapes its users' social and psychological processes, and it is therefore vital for learning that the users develop appropriate cultural tools". The concept 'appropriation' (Leont'ev, 1981a) of cultural tools has been used in socio-cultural theories to account for individual learning. However, analysis in this thesis does not utilise appropriation as a concept.

The instrumental approach accounts for learning both similarly and differently from activity theory. As a similarity, *mediation* is linked to the learning process which I will discuss in Section 3.4. However, the instrumental approach proposes the term 'utilisation scheme' to describe how learning takes place. I end this section with a brief elaboration of the nature of utilisation schemes where I conclude why I do not consider them beneficial to utilise in my analysis of teaching.

Rabardel argues that an instrument is a *psychological construct* consisting of an artefact and one or more associated and mutually dependent *utilisation schemes* developed for classes of tasks by its users. Rabardel's introduction of utilisation schemes, to account for how instruments are represented in the mind of human, seems to build closely on Piaget's notion of mental schemes. However, different from Piaget, Rabardel also includes the existence of *social schemes.* This expresses a view of scheme as the product of an assimilation activity where available artefacts and the environment with other people influence learning. Exemplifying with Cabri, over years ways of measuring and naming angles have evolved supported by the help menu, manuals and different kinds of teaching packages in Cabri. In Trouche's elaboration of the instrumental approach, he too refers to how users of artefacts develop utilisation schemes which he particularly links to the instrumentation process.

Such an emphasis on mental schemes, and at the same time a focus on social influence on learning indicate that the epistemological position of the instrumental approach (and the general theory of instrumentation) is a challenging one for a researcher elaborating a theoretical framework to analysis development in mathematics teaching. The instrumental approach combines terms usually considered to belong to either a cognitive or socio-cultural view on learning and hence needs careful elaboration. Drijvers and Gravemeijer (2005) make a distinction when they consider use of the instrumental approach in analysis of teaching. They argue that *utilisation schemes are individual*, while the *instrumental genesis* usually has a *social nature* which can be related to students and teaching within schools: "… we should notice that, although the instrumental genesis is often a social process, the utilization schemes are individual" (Drijvers & Gravemeijer, 2005, p. 168). Since my research emphasises teachers and development in mathematics teaching, not students and their learning, I lean on the above distinction which has guided my elaboration and use of the instrumental approach as a theoretical perspective. This is evident in Section 3.2 which emphasised teachers' orchestrations of students' instrumental genesis of Cabri, *not* students' and teachers' personal development of utilisation schemes. The nature and role of utilisations schemes has also been questioned. In fact, Monaghan (2007) argues that 'utilisation schemes' need to be elaborated more in order to be a helpful term in analysis of mathematics teaching.

In this section I have indicated how learning is treated within the two theoretical perspectives elaborated in this chapter. I end this chapter with a section (3.4) where I indicate how, despite these differences, I utilise the two perspectives in the later analysis.

3.4 Crossing perspectives in research of teaching development

Activity theory and the instrumental approach have roots back to the Soviet cognitive psychologists, particularly Vygotsky. They share emphasis on terms as indicated in the previous sections but there are differences related to how learning is accounted for. Critically speaking should these perspectives be used alongside each other and contribute in analysis of development in mathematics teaching like I proposed in the bullet list in the introduction to this chapter (see p. 58)? As argued in Section 3.2, the instrumental approach is a transition to mathematics learning of a general theory known to be grounded in a cognitive theory, by Haspekian (2005, p. 117) described as "a psychological and socio-cultural frame". Lerman (1996) argues that theories grounded in constructivist or cognitive view are totally different from and incommensurable with any kind of socio-cultural theories, activity theory included. Consequently, following the argumentation by Lerman, activity theory and the instrumental approach should not and cannot be merged. However, Rabardel and Samurçay (2001) argue that both the role of action and activity and the mediation of cultural artefacts fit well to the general theory of instrumentation as well as to activity theory. Drijvers and Gravemeijer (2005) also elaborate use of the socio-cultural term 'appropriation' when considering the role of instruments:

> The tool develops into an instrument through a process of appropriation, which allows the tool to mediate the activity (Drijvers & Gravemeijer, 2005, p. 166).

Although arguments such as those above indicate rather close connections between activity theory and the instrumental approach, I still see the perspectives as very different, rooted in different traditions and needed to be utilised in respect to this. To conclude, in this thesis I argue that the instrumental approach and activity theory contribute in *supplementary* ways to analysis of respectively teachers' *implementation* and orchestration of Cabri-*use* in mathematics teaching. With reference to Leont'ev's three levels to account for actions within activity (see Section 3.1.2, p. 61), the two theoretical perspectives offered in this chapter contribute to the framework in the following way:

- The role of intersecting activity systems, offered in activity theory, serve as crucial when I analyse teachers' *motives* for *implementation* of Cabri in Chapter 5. Intersecting activity systems also contribute to analysis of teachers' *goals*. Thus, both the upper and second level of Leont'ev is considered by utilising activity theory in the analysis.
- The instrumental approach utilised in Chapter 6 contributes to analysis related to the third level of Leont'ev; *operations* when teachers' orchestrate Cabri-*use* in mathematics teaching within *conditions* at the computer lab. In addition, teachers' efforts and ways of orchestrating the instrumentation and instrumentalisation processes are energised by their *goals* for teaching with Cabri. Hence, the instrumental approach with particular emphasis on mathematics and computer software use in teaching, contributes both to the second and third level of Leont'ev.

Combining theoretical perspectives is by Laborde and Perrin-Glorian (2005) argued to potentially be "a good way of grasping the complexity"

(p. 8) when analysing teachers' practice. Two ways of doing this is according to Laborde and Perrin-Glorian either "crossing two perspectives on the same object of study or linking concepts coming from different theories" (p. 8). I assert that my use of the two theoretical perspectives is best in accordance with Laborde and Perrin-Glorian's first argued way of using two theoretical perspectives: "crossing two perspectives on the same object of study". However, I utilise the perspectives in analysis of implementation process and orchestration of the tool in use which are related to teachers' practice but also different. I do not directly link "concepts coming from different theories" but the theories propose similar or different use of the same terms such as mediating artefact, subject, object and meditation, and both theories consider contribution by Vygotsky and colleagues as crucial.

To summarise, I argue that I have accounted for supplementary use of the theoretical perspectives on two aspects of teachers' practice. The supplementary use of the perspectives is further outlined in Section 4.7.4 which gives an entrance to the analysis chapters 5 and 6.

4 Methodology and research design

In this chapter I outline and discuss the design and evolution of my case study with teachers situated within two developmental projects. The case is outlined in Section 4.2.2 and is about three teachers and their development in teaching when implementing and orchestrating Cabri-use in teaching for the first time in their teaching career. Throughout the chapter I consider my own and colleagues' role as didacticians and researchers within the LCM and ICTML developmental projects, and *how* didacticians and other teachers in the projects created opportunities for teachers and influenced development in teaching. I discuss ethical considerations and concerns for trustworthiness of my research, research methods and processing of data. The chapter ends with an introduction to the data analysis in Chapters 5 and 6.

4.1 Research of teaching within developmental projects

As a didactician it was my responsibility to *support* the teachers in development of teaching where both didacticians and teachers aimed to benefit from the close involvement. I have acknowledged that such support was aimed to empower both teachers' implementation of computer software and inquiry in their mathematics teaching (see Section 2.3.2, p. 49). The collaboration between didacticians and teachers for three years created extensive opportunities for me as a researcher to *interpret* teachers' implementation process and orchestration of computer software use in mathematics teaching. I consider myself therefore as an insider in this research rather than an outsider to what I observed and issues that rose for my research and the findings, conclusions and implications I suggest in this thesis.

In the following subsections I first (4.1.1) pay attention to different kinds of *influences* on what I observed in my study and what kinds of consequences that raises. In Section 4.1.2 I comment critically on the nature of interpretations I present in this thesis, and I argue why I consider my role as being an *interpretive researcher studying and supporting development in mathematics teaching*. After introducing and classifying my case study in Section 4.2, Section 4.3 gives a further treatment of my role as didactician and researcher in different kinds of sessions with teachers in the projects.

4.1.1 A study of development influenced in several ways

The combination of specific aims of my research, the wider developmental aims of the projects and teachers own goals and intentions with participation in the projects, contributed to my perspective on teachers' implementation and orchestration of computer software use in teaching. I start off by paying attention to the *influential roles* of *didacticians* and *teachers* on what I observed. Three main kinds of *influences* are discussed below:

1) My personal position and aims for my research within the ICTML project.
2) Presence of and suggestions from didacticians in different kinds of sessions in the LCM and ICTML projects.
3) Teachers' and schools' intentions concerning their participation in the LCM and ICTML projects.

I *first* consider how my personal position and aims influenced my contributions in sessions with teachers, in what kinds of sessions I participated, and how my contributions were interpreted by the teachers. I wanted to be frank with the teachers emphasising that my main priority was to observe and contribute in sessions where teachers considered implementation of computer software and to observe use of such software in mathematics teaching. However, in order to avoid an isolated focus on computer software use I also wanted to take part in:

- sessions where computer software were not used or discussed, such as lessons with use of compasses;
- the wide spectrum of workshop- and school sessions in the projects, including meetings and interviews, some related to computer software but many not.

In sum, the possibility to attend and participate in these different events supported a wider perspective development in mathematics teaching.

Secondly, presence and suggestions from didacticians in different kinds of sessions were also influential. The teachers were introduced to aims of the developmental projects and worked with tasks and different kinds of tools in workshops at UiA, and didacticians participated in meetings, conversations, classroom- and computer lab visits in the schools overall suggesting communities of inquiry as a proposed outcome. I realise that didacticians' and other teachers' presence and contributions in sessions influenced what I observed. For example in conversations, didacticians' presence led teachers to consider elements in their teaching which they otherwise would not have addressed or not addressed in the same way. Such experiences are emphasised by Jaworski (1994) in a study where she collaborated for a long time with teachers. She argues that the collaboration stimulated questions such as:

- What do I do in my teaching?
- Why am I doing it in this way?
- What is the potential of computer software tools in this respect?

In my research study, some teachers started to consider and gradually implemented computer software tools like Cabri and Excel suggested by didacticians in the ICTML project. The teachers discussed issues concerning implementation of the software and how to orchestrate use of the tools at their schools. They shared their efforts and experiences from teaching during sessions in the developmental projects and in conversations in school.

Thirdly, teachers' and schools' intentions concerning their participation in the LCM and ICTML projects also influenced on what the teachers and their school leaders emphasised in sessions. The schools volunteered to join the projects and signed contracts regarding participation. As a consequence, both the schools and teachers potentially had some aims or at least some *intentions* concerning roles in the projects and what they wanted or expected to achieve with their and didacticians' participation.

As indicated, the nature of my research study within the developmental projects offers good possibilities for insight to teaching and development of teaching in schools. However, the close collaboration between teachers and didacticians also raises issues for me as a researcher when I consider teachers' development in teaching. The latter is considered further in Section 4.1.2.

4.1.2 Interpretive researcher studying development

I study teachers in the social context they were part of, both as teachers at their schools and members of the developmental projects. I therefore have to interpret teachers' contributions within these contexts. As humans we communicate but *what* we communicate is typically based on our personal interpretations of something "real" and not an objective reality:

> Because of differences in perception, in interpretation and in language it is not surprising that people have different views on what is real (Bassey, 1999, p. 43).

Thus, I consider reality to be how each person interprets it, dynamic and influenced by other people. Building on my activity theory perspective (see Chapter 3), I see my interpretations of teachers' implementation of a computer software tool as my appropriation of activity systems where I am part of the community. Despite my quite regular observations of teaching and conversations with the teachers, my own and colleagues influence on the teachers in the projects can not be *disregarded*.

I do consider as a big benefit to have conducted a study of teachers that I knew so well for many years in the projects. However, there is a danger to "look" for evidence of influence from the developmental projects in teachers' teaching. The teachers might indicate, both by their teaching and things they express, that they were affected by the projects including didacticians and other teachers. But to *which extent* were they affected and did it lead to other kinds of actions and considerations by the teachers? The teachers knew that I was a didactician and researcher within two developmental projects and could be strongly affected by this fact. In their answers they could express what they *believed I wanted* to hear or what they believed they were *supposed to* say as part of the philosophy of the projects. The teachers' answers could also be quite *casual* because they did not think of anything else to say which particularly could be an issue in interviews where the teachers were asked to address questions. I discuss the concerns commented in this paragraph in later sections when I consider my role as didactician and researcher (Section 4.3), ethical concerns (Section 4.4) and data collection (Section 4.6). As part of my introduction to analysis of data in Section 4.7, I also indicate how interpretations guided my processing of data.

In the analysis I try to interpret the *how* and *why* aspects of teachers' implementation and orchestration of Cabri-use. I believe this approach fits well with Carr and Kemmis (1986) consider as aims for an *interpretive researcher*:

> Seen from the interpretive researcher's point of view, actions have meaning in relation to the understandings, purposes and intentions of the actor, and the actor's interpretations of the significance of the context of the action (Carr & Kemmis, 1986, p. 92).

Thus, teachers' comments and teaching are both interpreted in light of the social and cultural context in which they are working and the developmental projects and teachers' experiences of the projects in relation to their purposes and intentions. In my research, the developmental elements were ongoing. In order to have conclusions and implications to share with others, like researchers, teachers and policy makers, the role of the developmental projects and development as such are key elements in my study, obviously, because most teachers in Norway do not have the possibility to participate in such projects. After all, to share findings is the overall key task for research, or as Bassey (1999) states it, a purpose:

> To the interpretive researcher the purpose of research is to advance knowledge by describing and interpreting the phenomena of the world in attempts to get shared meanings with others (Bassey, 1999, p. 44).

Since developmental projects aim for stimulating and studying developmental processes, I argue that I worked as an *interpretive researcher studying and supporting development in mathematics teaching*.

4.2 A case study research design

Section 4.2.1 contains a brief discussion of *why* I use a qualitative research strategy and case study design in my research. The nature and evolution of my case study is outlined in Section 4.2.2. In Sections 4.2.3 and 4.2.4 I discuss how the case study offers generalisation possibilities and I give a classification of the case study.

4.2.1 Qualitative research strategy

Gorard (2001) argues that researchers often choose research strategy before deciding what to research and recommends: "You must decide on your research topic and the questions you are curious about first, and only then consider how best to answer them" (Gorard, 2001, p. 8). I read this warning from Gorard at an early stage in my Ph.D. study, and his warning worked as guidance in my own process of choosing research strategy. At an early stage I considered combining qualitative and quantitative strategies by conducting a survey with schools and teachers in Norway. However, when I gradually framed the research questions and considered the aim of my study within the ICTML project, I concluded that qualitative strategies suited my purposes best. I wanted to focus in depth on the teaching of a limited number of teachers.

4.2.2 The development of a case study

My study involved three teachers who implemented and orchestrated Cabri-use in their teaching for the very first time in their teaching career. Data was collected during many years in different sessions in the projects. These data provided me with an in-depth perspective to teachers' development in teaching such as the issues and reasons raised by the teachers in their implementation process of Cabri. Although I study two teachers at one school and one teacher at another school, I treat them as *one* case because of the mutual content and situatedness. They all:

- worked at Grade 8;
- were newcomers to Cabri and implemented Cabri for the first time;
- accomplished their first ever teaching with Cabri almost at the same time;
- participated in the same developmental projects and contributed to each others implementation process for example in workshop sessions.

These similarities and influences explain why I do not consider the three teachers as three separate cases or one case from each school. An advantage with this kind of a case was also its potential to help me in suggesting alternative interpretations and illuminating differences and similarities between schools and teachers. This indicates that elements of cross-case analysis within the case are included and contributes to a generalisation process.

I believe that the phenomenon focused on in the case could communicate well with many mathematics teachers at lower secondary schools in Norway when they consider implementation of Cabri, other kinds of DGS[18] or other types of computer software in mathematics teaching. I also argue that the role of developmental projects could be of interest for the founders of developmental projects, policy makers, researchers and

[18] DGS as an abbreviation for a dynamic geometry software package such as Cabri was introduced on page 32

teachers either involved or not in developmental projects.

4.2.3 What the case study offers

In Section 4.2.2 I presented reasons for my design of a case study with three teachers. In this section I consider critically what kinds of conclusions and implications I can suggest from this case. Despite the benefits described in the previous section, my case was deeply *contextualised* within two developmental projects and a number of schools. Such contextualisation-issues seem close to Stake's (1995) description of typical features of case studies:

> Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances (Stake, 1995, p. xi).

Thus, *generalisations* based on findings in the case study seemed to be difficult to claim, at least in the way the term generalisation typically is used in mathematics. To compare findings from my case study with findings from other case studies and indicate a generality of such findings to other cases should be treated with great caution. In such senses I very much find my view supported by Pring's *warning* about generalising findings from case studies:

> Such bits of knowledge, even when added to lots of other bits, cannot become context-free knowledge which permit the law-like generalizations wanted by government and systematic reviewers (Pring, 2004, p. 139).

I rather wanted to bring attention to *characteristics* and *issues* illuminated in the case study in order to suggest implications from findings to other cases related to the three main target groups for my thesis: *teachers*, *researchers* and *policy makers*. In such senses I believe my case study can contribute with *shared meanings* as illustrated in the earlier presented quotation from Bassey (see Section 4.1.2, p. 90). Bassey also explicitly argues that case studies contribute to possible *generalisations about an instance*, but I rather use the phrase *generalisation in depth* in this thesis emphasising issues and processes evolving within the case. To add to this, Delamont and Hamilton (1993) challenge the criticism concerning lack of possibilities to generalise findings in case studies. They refer to potentials of case studies which seem to be close to what I have phrased as generalisations in depth:

> Despite their diversity, individual classrooms share many characteristics. Through the detailed study of one particular context it is still possible to clarify relationships, pinpoint critical processes and identify common phenomena. Later, abstracted summaries and general concepts can be formulated, which may, upon further investigation, be found to be germane to a wider variety of settings (Delamont & Hamilton, 1993, p. 36).

It is such relationships, critical processes and common phenomena I emphasise when I later highlight *issues* and *tensions* in the analysis in Chapter 5. I consider my case study to support my aim of generalisation in depth since the case involves three teachers at two schools participating in the same developmental projects and who implemented Cabri close in time. Thus, to compare these teachers' implementation processes and orchestration of Cabri-use, who in many ways were related, offers me a possibility to suggest implications based on conclusion from my study.

4.2.4 A classification of the case study

To describe further generalisations which are reasonable to suggest based on my case study, I associate my case study with a categorisation of five kinds of educational case studies made by Bassey (1999). Above I emphasised different elements in the case study I have conducted. It is a case study emphasising a *timeline* of issues addressed and decisions made by the teachers in their implementation process of Cabri. In my activity theory analysis, this is interpreted as development resulting in a shared object in teaching made possible when teachers addressed issues in order to overcome tensions in their practice. During teaching, Cabri evolved as a cultural tool when students used Cabri orchestrated by their teachers. This way of studying and analysing the *process* of teachers' implementation and use of Cabri in mathematics teaching seems close to what Bassey characterises as a *story-telling case*:

> Story-telling is predominantly a narrative account of the exploration and analysis of the case, with a strong sense of time line (Bassey, 1999, p. 62).

My case with three teachers emphasises development in teaching occurring within projects which highlight such development in teaching. Since development obviously takes place over time this contributes to the story-telling elements of the case. The inclusion of several teachers in many different sessions, the longitudinal character of the case, illumination of issues during the process and how they were handled are elements which I use to contribute to the trustworthiness of conclusions and implications I made based on analysis of my case study.

My two research questions (see Section 1.3, p. 24) emphasise teachers' motives and goals energising their implementation of Cabri and their orchestrations of Cabri-use in teaching. In order to answer this, a focus on teachers' developmental process when implementing and initially using Cabri in teaching is important. This illustrates a story-telling character of my case study. As already argued, I do believe the case and analysis will show how I *also* deal with data across a timeline looking for coherence and lack of such within the case. In such senses I believe my case study also shares characteristics with Bassey's *picture-drawing cases*:

> Picture-drawing is predominantly a descriptive account, drawing together results of the exploration and analysis of the case (Bassey, 1999, p. 62).

Bassey argues that picture-drawing case studies and story-telling case studies share an emphasis on giving "theoretical insights, expressed as a claim to knowledge" (p. 62). This supports my claim that the case study gives me a basis for proposing conclusions and suggesting implications, and the study involves both picture-drawing and story-telling elements. It is more than a story of events which can be a problem with case studies that exaggerate the story-telling aspect.

4.3 Research roles

In this section I consider my role as a didactician in sessions with teachers. This is a follow-up on concerns for influences on what I observed already raised in Section 4.1. Later, in Section 4.5 I describe the data gathered in these different sessions with teachers while my methods of data collection are considered in Sections 4.6. When I present conclusions and suggest implications in Chapter 7, concerns for my role as didactician and influence on findings are discussed.

In the coming subsections I argue that my role in most sessions with teachers was a combination of being a participant and observer. In conversation with teachers at their schools and in group sessions at workshops, I was usually a quite active participant which, with reference to Gold below, I describe as *participant-as-observer* role. He describes such kind of role as the typical role within a community:

> Probably the most frequent use of this role is in community studies, where an observer develops relationships with informants through time, and where he is apt to spend more time and energy participating than observing (Gold, 1958, p. 220).

During classroom and computer lab visits my role was less active than in conversations. I mainly observed the lesson but was also active either when students asked me for assistance or the teachers came and talked to me during the lessons discussing the teaching and students work. Thus, I will describe my role in these sessions as an observer-as-participant. The two mentioned roles above are the roles marked as 2 and 3 below. This list with four roles builds on a categorisation of the *participant observer roles* made by Gold (1958):

1. Complete participant
2. Participant-as-observer
3. Observer-as-participant
4. Complete observer

Gold argues that in order to be a complete observer, my identity could not be known to the people I observed. Since this was not true, it is not a good description of my role. The only situations where I interpret that I behaved close to being a complete observer, occurred when I joined general staff instruction meetings which happened two times when I sat with teachers in their staff room. The co-learning agreement (see Section 1.2, p. 21), on which the projects were based, could be interpreted as aiming to have both teachers and didacticians as complete participants, particularly in sessions designed by the projects where didacticians and teachers were together discussing mathematics teaching. However, I believe because of the two groups' different backgrounds, interests and expertise, it is reasonable to describe my role on a scale from observer-as-participant to participant-as-observer and in some sessions also a complete participant. In the coming subsections I give more details to the different sessions and my role within these.

4.3.1 Informal conversations at the school and in workshops

As part of my visits to the schools, I usually talked with the teachers some minutes before the lessons and some minutes after the lessons dependent on whether or not the teacher had time for this. In conversations ahead of the lesson, I usually asked the teachers to say a little bit about the lesson and after a few times the teacher told me this without being asked. The conversations were often very brief, typically on the way to or from the computer lab or in the staff room if the teachers had available time. In these brief conversations, the teachers often asked for feedback to his/her lesson plan with questions such as "What do you think (of the lesson)" and "I do not think my students worked well today. Do you agree"? Thus these conversations involved me as an active participant but after a while more as a *participant-as-observer* since the teachers started to talk about their lessons without waiting for my comments or questions.

In the workshops in the two projects, in total sixteen and twelve workshops respectively in the LCM and ICTML projects, part of the time was reserved for group sessions. In the LCM project, these group sessions included 3-4 teachers and 1-2 didacticians while in the ICTML project with fewer participants usually everyone gathered around a big table. The group sessions lasted for approximately 45 minutes and were in the LCM project usually followed by a plenary with presentations from group members. All the participants in the groups were supposed to contribute and be active. Didacticians were supposed to give support to the teachers during the group session by offering questions and asking the teachers to offer their contributions. In some of the group sessions in the workshops, the teachers reported from their teaching and were given feedback and asked for further elaboration by didacticians and sometimes other teachers. Thus, both during the informal conversations with teachers in schools and group sessions in workshops, my role was typically that of a *participant-as-observer* in Gold's terms.

4.3.2 Classroom and computer lab observations

In my first visits to teachers' classes, I briefly introduced myself and indicated my role as mainly wanting to observe the teaching. Thus, the teachers and the students knew who I was and had got some information about my role and what I wanted to achieve. In my first visits to a class, I used to walk around in order to get to know the students and vice versa.

As my observations went on, I gradually got a more passive role usually operating a video camera and talking with students if they encouraged me to do so. The latter indicates why I classify my role in the classroom and computer lab as typically being an *observer-as-participant*. I observed the lessons and participated only to a limited degree mainly if the teacher or students called on me. Classrooms and computer labs were vital arenas for my collection of data in order to observe how teachers orchestrated students' work with Cabri in their mathematics lessons.

4.3.3 Plenary sessions in workshops and at a conference

Workshops in the two projects also included working sessions at computer labs and plenary sessions where all the participants in the projects were present and both didacticians and teachers contributed. In these sessions, one or two didacticians orchestrated the plenary and were active participants. During teachers' work at the computer lab and teachers' presentations in plenaries, didacticians mainly had the role of an *observer-as-participant* except for some short parts where didacticians were more active and contributed as participant-as-observer. In a conference for teachers, arranged as part of the last year of the developmental projects, teachers at each school in the project made a school conference presentation emphasising school development issues. In these sessions, didacticians were supposed to be passive only introducing and thanking the teachers and in some of the sessions responding with a couple of questions during and after their presentation. Thus, in these plenaries didacticians' role best can be described as an *observer-as-participant*.

4.3.4 School team meetings with teachers

In this section I pay attention to school team meetings with teachers. The establishment of school teams had been proposed by didacticians in the developmental projects and in the contract for schools' participation in the LCM project. The team at each school was supposed to include the teachers who participated in one or both of the developmental projects; if suitable, the principal or vice principal at the school and a few didacticians given special responsibility for follow up on each school.

The nature of the school meetings affected whether or not my role (and the other didacticians' roles) could be seen as a participant-as-observer or observer-as-participant. Some school meetings were *requested* by didacticians partly with didacticians' agenda. An overall aim for didacticians with such meetings in teams was to stimulate and get involved in the work and community building at each of the schools. Didacticians wanted to be informed about teachers' work in school related to the projects in order to support teachers in their development in teaching. Thus, in school team meetings didacticians' roles varied from a *participant-as-observer* to an *observer-as-participant* role. The role was often quite *active* proposing support and specific actions in schools such as presenting an approach to use of computer software.

4.3.5 Interviews

According to Gold, interview is the typical method involving an observer-as-participant role of the researcher. I only accomplished interviews four times in my research study; once with a didactician and three times with teachers.

All the interviews were *semi-structured.* I had planned the interviews and had some questions I carefully considered if were addressed by the teachers or not during the interview. I also wanted the teachers to talk about their experience from teaching and potentially to raise issues based on their teaching which included use of computer software in mathematics teaching and other kinds of approaches to mathematics teaching.

The interviews with the teachers were arranged as *focus group interviews*. The participants discussed a specific issue or theme like their implementation and teaching with Cabri and development and participation in the projects. The arrangement of focus groups made it possible to focus on the ways teachers discussed issues as a group and responded to each other's view. In fact, I argue that such discussion was in accordance with and part of the development of a co-learning community of teachers and didacticians utilised by didacticians in arrangement of workshop sessions. In workshops, teachers were grouped working with mathematics and discussing implementation of ideas to their mathematics teaching. These different arguments indicate that to interview the teachers separately would be to deny much of the desired community development where teachers talked and discussed efforts and issues in teaching and also assumed to be more unnatural for the teachers. Bryman (2004) presents implications of focus group interviews which share my aim and arguments above for conducting the interviews in this way, some of them cited below:

> In the context of a focus group, individuals will often argue with each other and challenge each other's views. This process of arguing means that the researcher may stand a chance of ending up with more realistic accounts of what people think, because they are forced to think about and possibly revise their views. ….. The focus group offers the researcher the opportunity to study the ways in which individuals make sense of a phenomenon and construct meanings around it. …., focus groups reflect the processes through which meaning is constructed in everyday life and to that extent can be regarded as more naturalistic (Bryman, 2004, p. 348).

Bryman's implications of focus group interviews indicate advantages of focus group interviews which helped me to have a more realistic account of issues related to teaching mathematics. On the other hand I also see possible problems in this way of conducting interviews. One problem could be to involve all the teachers and make sure that every teacher contributed. During the interviews I sometimes explored views coming up from the group sometimes directing questions to individual teachers in order to take care that different views came up. My way of collecting data during interviews indicated in this section is discussed more extensively in Section 4.6.

To summarise, I argue that the interview I conducted in my study only partly supported Gold's claim of interviews as involving an *observer-as-participant* role of the researcher. I do believe that I *also* had a *participant-as-observer* role, especially when formulating questions and at some points during the interviews. The very nature of the developmental projects, where the teachers were used to discuss teaching and issues related to development in teaching with didacticians, made it reasonable not to conduct interviews as a number of questions supposed to be answered. It was rather conversations where the teachers also raised questions and issues and I as the interviewer contributed to the discussion.

4.4 Dealing with ethical issues

In this section, I pay attention to ethical issues. In the previous section (4.3) I considered my role as didactician in different sessions with teachers. As a follow up, in Section 4.4.1 I discuss more overall concerns related to my way of *acting* as a didactician in the field. Section 4.4.2 emphasises ethical issues considered when *writing* this thesis. Use of pseudonyms, presented in Section 4.4.3, is one concrete effort made to support confidentiality of teachers, students, schools and didacticians within the projects.

4.4.1 Critical concerns when acting as a didactician

When working with teachers and students, ethical issues might arise. What if I noticed that a student made a mistake or one of teachers used Cabri ineffectively or basically wrongly, for example not constructing a 60 degree angle although claiming doing so? After a while my main approach, the few times I observed such situations, was carefully to probe and challenge the students or teacher by having one to one conversations where we discussed what had happened. This is close to the approach described by Goodchild (2001, p. 108) in his field work. By such an approach I kept my own professional role as mathematician and researcher alongside my role as a didactician and learner only partially participating in the actions. This also relates to a basis in the LCM project: didacticians and teachers were seen to bring different expertise where teachers were the experts of mathematics teaching in schools.

To have a brief guide to manage my actions as didactician and researcher was experienced as being helpful. In an early phase of my reading, I considered a list of four criteria from Cooper and McIntyre (1996, p. 26-27) as valuable in preparing for my contact with teachers. Cooper and McIntyre give guidelines which I found challenging but crucial in research with close collaboration with teachers:

1. Empathy
2. Unconditional positive regard
3. Congruence
4. Repeat probing

I see *empathy* as my ability to communicate respect and sympathise with the students and teachers, for example when the teachers responded with uncertainty and dissatisfaction after one of his/her lessons. I had an *unconditional positive regard* by indicating personal interest in teaching, teachers' efforts and to students as individuals. *Congruence*, or a congruent attitude, means that I tried to interact with teachers in a way that the teachers experienced as honest, authentic and thus potentially motivated the teachers to give their own authentic responses. Finally, by the phrase *repeat probing*, I accepted, during for example interviews, that questions were not answered and instead I sometimes went back to the question or rephrased it later if an opportunity arose. I believe these four criteria from Cooper and McIntyre had increased value for me as a researcher and didactician within developmental projects compared to being researcher with not a defined developmental aim and responsibility.

4.4.2 Ethical issues concerning writings in my research

A critical issue for my research is how to report from the research situated in developmental projects with collaboration between teachers and didacticians for several years. In particular, *confidentiality* should be emphasised since the projects aimed for collaboration and development in teaching and thus potentially could place easy traceable teachers in bad light. Pring addresses confidentiality more generally as an important issue for a researcher:

> How far can one ensure confidentiality or clearance of research findings without jeopardizing the objectivity and independence of research (Pring, 2004, p. 151)?

What Pring does in this quotation is to warn against hiding crucial elements from research findings for the sake of confidentiality. In my view, this is a very central issue in educational research, my own research included. Pring answers the question by focusing on *five* areas of importance for the researcher to keep in mind. According to Pring, the researcher must:

- be explicit to the kinds of knowledge required;
- keep the anonymity of my sources even if it makes the contextualisation of my research more troublesome;
- be ready for cross-examination of the way my research is conducted;
- give my informants the possibility to give me feedback;
- be aware of the possibility that other may misuse my results.

In this thesis, students, teachers, schools and didacticians, except me, are referred to with pseudonyms (see Section 4.4.3). As mentioned, I experience keeping confidentiality to my teachers as particular challenging since the teachers were part of a recognisable group of teachers in the ICTML and/or LCM projects, a piece of information which I found as crucial for the reader and could not hide. Similar comments could be made about didacticians and students, but my main critical focus in the thesis is on teachers and to some extent didacticians. What if my findings for example indicated a lack of fulfilling requirements in the curriculum or personal issues were brought up by the teachers? However my research questions essentially focus on teachers' use of Cabri and with which motives teachers' implemented computer software in mathematics teaching. Thus, it is not a kind of study where I focus on making normative judgements on teachers' practice.

In order to address issues related to claims I present about teachers and didacticians, I have asked teachers and didacticians to give me comments, both in written form and through conversations about the work. This was done ahead of presentations at conferences and in a book chapter in a Norwegian book. Didacticians and in particular my supervisors have given me extensive comments about claims presented in this thesis. This also addresses some of the main issues of *trustworthiness* of my research. With the help from researchers and teachers, I hope I have been able to avoid too subjective and limited interpretations and that I have used efficient enough tools to keep the confidentiality of the teachers at a satisfactory level for all involved in the research.

To keep the confidentially in the future, I will exercise extreme caution in presenting video recordings from sessions with teachers and students, especially in the local area in Norway where my data have been collected. Indeed, if I want to present video or audio of this kind, I explicitly said to the teachers that I will ask for permission each time and only use examples which I believe exemplify positive elements in teaching.

4.4.3 Use of pseudonyms

In Section 4.5 I introduce names of the teachers who contribute to my case. Teachers' names, names of schools, didacticians and students are pseudonyms. The length of the pseudonyms used in the thesis has the following differences aimed to help the reader:

- Teachers' pseudonyms consist of 5 or 6 letters.
- Students' pseudonyms consist of 4 letters.
- Didacticians' pseudonyms consist of 3 letters.

Teachers', didacticians' and schools' pseudonyms are common designed and used by didacticians in the developmental projects. Myself as the author of this thesis is the only didactician referred to with real name.

4.5 The pilot and main study

In this section I first (4.5.1) briefly describe the pilot study. In Section 4.5.2, the main study is described including selection of teachers and schools involved and the three main teachers in my study.

4.5.1 The pilot study

Towards the end of the first year of my Ph.D. study, I considered use of case study design as an appropriate choice based on the possibility to follow a number of teachers quite closely during the three years of the developmental projects. Thus, in the spring 2005 I conducted a pilot study. The pilot study was supposed to serve several objectives:

- Be a possibility to get some experience in being a researcher within the developmental projects. Get some practical experience, included use of methods like interviews and participant observations during teaching in classrooms and computer labs.
- Get some indications as to whether the methodology and theoretical framework were feasible or not for the analysis and consider adjustments.
- Be an important source in the further development of my research questions, theoretical framework and methodology.
- Build confidence and trust among the teachers in the project and their students in order to carry out the main field work in 2005/2006.

The field work related to the pilot study highlighted two mathematics teachers working at Grade 9 at Vestpark, one of the schools in the ICTML project. I participated in their planning phase of a number of lessons in school team meetings and observed three lessons. I had a conversation with one of the teachers who was available for a conversation after two of the lessons. I also conducted a focus group interview with the two teachers using video recording from one of their common lessons as a resource.

I visited the other three schools and teachers in the ICTML project as well in order to prepare for field work in 2005/2006. I transcribed data from the mentioned sessions at Vestpark and analysis of these data contributed to a conference research paper: “Teachers reflections on the use of ICT tools in mathematics: Insights from a pilot study”. The paper was reviewed and published in the conference proceedings (Erfjord & Hundeland, 2007).

4.5.2 The main study

Use of Excel and Cabri was considered in workshops in the ICTML project which started in August 2004. As mentioned, I had a research interest in teachers’ implementation and orchestration of use of such computer software tools in their mathematics teaching. I had visited several teachers at the four schools in the ICTML project, Austpark, Dalen, Fjellet and Vestpark, and continued in autumn 2005 to visit these four schools more regularly. This was also part of the agreement in the projects that I, as a didactician, was supposed to have contact and support teachers at the schools, which for me particularly was expected to be support related to the ICTML project. As part of the agreement in the projects, there were meetings between didacticians and teachers in schools as well as workshops at UiA.

In a school team meeting at Austpark in October 2005, two of the teachers exposed a plan to use Cabri for the first time in their teaching careers. The teaching was accomplished in their classes at Grade 8 in January 2006. In a workshop session early in January 2006, one of the teachers at Fjellet informed didacticians that she too, five days earlier, for the first time in her teaching career, had started to use Cabri in her class at Grade 8. Hence, three teachers at two of the schools in the projects, Austpark and Fjellet, implemented and started to orchestrate use of Cabri in their mathematics teaching in January 2006. The two teachers at Austpark, Jakob and Frode, and Trude at Fjellet eventually constituted what I, in Section 4.2.2, described as my *case study*.

Jakob, Frode and Trude

Jakob entered the projects in their second year for schools when he got a temporary full teaching position at Austpark. During his two years at Austpark, from August 2005 till June 2007, he mainly taught mathematics and natural sciences. In June 2005 he had completed the first of two years in a master programme in mathematics didactics at UiA. He completed his final year of the master program during the two years he participated in the projects and worked at Austpark. His earlier educational programme included a subject teacher education programme in natural sciences, ICT and mathematics. Consequently, Jakob was a newcomer as teacher when entering the projects. Although he started his participation in the projects one year later than most of the other teachers, he had some experience with the LCM project as a master's student responsible for video recordings in two of the workshops. He participated in the projects until the schools' participation in the projects was finished in June 2007. Jakob left Austpark and got a new position as teacher at another school in Norway where he started to work in August 2007.

Frode participated in the LCM project from the start in August 2004 until January 2007 when he got a leader position at another school. He had his first job as teacher in 1997, and he worked at Austpark from 2000 till 2007. His educational programme ahead of 1997 included the four year General Teacher Education programme. Like many teachers accomplishing this programme, Frode's work involved teaching most of the school subjects at lower secondary school including mathematics, Norwegian, social studies, physical education, English and natural sciences. As well as the General Teacher Education programme, Frode had accomplished a study in informatics and a course in school development and management at UiA alongside his job as teacher at Austpark. He also worked as a practice teacher for teacher students in their General Teacher Education programme at UiA. During his career as mathematics teacher ahead of the projects, the only computer software he had used in his teaching was Excel.

Trude participated in both of the projects from the start in August 2004 but stopped her participation in March 2006 when she took a break from teaching for the rest of the school year. Trude had been a teacher since 1974 after finishing a three year General Teacher Education programme which at that time approved teachers to teach in primary and lower secondary school (Grade 1-9). Her educational programme also included half a year with mathematics as well as half or one year programmes in other school subjects such as Christianity, physical education and history. Trude had also worked as a practice teacher for teacher students in their General Teacher Education programme at UiA for ten years. Alongside her participation the first year of the projects, she had a full time job as vice principal substitute. Trude had started her teaching career as a teacher in primary schools, worked two years at an international school in Asia and from 1991 in lower secondary school.

Ahead of the projects, all the teachers at Austpark and Fjellet reported minimal use of spreadsheets as the only mathematics related computer software tool used in their mathematics teaching. The teachers at Austpark reported that their use of Excel had been organised as a course, not particularly mathematics related, which I have described as a frequent used approach with spreadsheets in Norwegian schools (see Section 2.2.2, p. 35). Trude argued that her use of spreadsheets had been very limited in the past. This illustrates that Jakob, Frode and Trude and their students had quite limited experience in use of computer software tools in mathematics teaching.

At Austpark they had a big computer lab with modern computers, a room with older computers and a set with approximately 12 portable machines and a portable projector to be shared between 15 classes. Most of Jakob and Frode's teaching with computer software occurred in the big computer lab quite a distance from their classrooms. The computer lab had 28 computers and a mounted projector connected to a computer in front of the room. Jakob also used the portable machines and projector in some lessons occurring either in a classroom or in another available room. Fjellet had a computer lab with 20 computers and a set with approximately 15 portable machines and a portable projector to be shared between ten classes. The computer lab was upgraded and unavailable during Trude's teaching period with Cabri. Thus, Trude's Cabri teaching occurred in her classroom with the school's set with portable machines. Trude never used any video projector but portable video projectors were available at the school.

Other teachers and another case

The two schools, Fjellet and Austpark, participated with respectively three and five teachers at lower secondary grades in the two developmental projects. Some of the teachers participated in both projects, some only in one of the projects, and four mathematics teachers at Austpark (Eivind, Sigurd, Robin and Runar) did not participate in any of the projects. The situation in Year 2 of the projects, the main period for my data collection, is illustrated below in Table 4.1. The table also illustrates that some of the teachers participated all three years and others not. The reason why they did not participate all three years was that these teachers did not work all the three years at Austpark or Fjellet either because of changes in teaching positions or a break from teaching:

Table 4.1: Mathematics teachers, Grades 8-10 2005/2006, at Austpark and Fjellet and their extent of participation in the developmental projects

2005/2006	Austpark	Fjellet
Mathematics teachers at Grade 8	Jakob: (LCM and ICTML, Year 2 and 3) Frode: (Only LCM, Year 1,2 and half of 3) Eivind: (None of the projects)	Trude: (LCM and ICTML, Year 1 and ¾ of Year 2)
Mathematics teachers at Grade 9	Harald: (LCM and ICTML, Year 1, 2 and 3) Gunnar: (LCM and ICTML, Year 1, 2 and 3) Sigurd (None of the projects)	Markus: (LCM and ICTML, Year 1, 2 and 3)
Mathematics teachers at Grade 10	Elise: (Only LCM, Year 1, 2 and 3) Robin: (None of the projects) Runar: (None of the projects)	Ludvig (only ICTML, Partly Year 1 and 2)

In addition to Jakob, Frode and Trude, four other teachers at the schools implemented Cabri during the school year 2005/2006: Eivind, Harald, Gunnar and Markus. The contributions from Harald and Gunnar are considered most important in my case since they contributed in school team meetings with Jakob and Frode while Eivind obviously was not part of these since he did not participate in the projects. Markus did not inform didacticians about his use of Cabri, which occurred many weeks after the other teachers' use of Cabri, neither in school team meetings nor workshop sessions.

Findings in Chapter 5 indicate that Jakob and Frode considered Eivind's use of Cabri as important in their own implementation process with Cabri. Since Eivind was not part of the projects, he never attended any sessions in the projects and I did not observe his teaching. Altogether I argue that in addition to Jakob, Frode and Trude, the case needed to take into consideration contributions from:

- the other participating teachers in the projects at the two schools;
- their non-project participating colleagues;
- school leaders;
- teachers at other schools in the project;
- didacticians at UiA in workshops, meetings and interviews.

Vestpark was central in the pilot study and I had expectations for the school's contribution to my research study. However, the school had access problem to Cabri and the teachers chose to use computer software very little. Since I wanted to consider teachers' implementation and orchestration of computer software use, such limited use would offer little contributions apart from emphasising lack of use of computer software in teaching. These kinds of limitations are well documented like in the quoted research papers and surveys in Section 2.2.1.

Similar to Fjellet, Dalen was a school with only one class and thus only one mathematics teacher at each grade. Nevertheless, Dalen was in another position than the three other schools in the ICTML project. Before entering the ICTML project, the mathematics teachers at Grade 8-10 at Dalen, Otto, Rikard and Viktor, were already experienced with use of computer software. Otto was at the time the most experienced mathematics teacher with many years experience of using computer software in teaching. He also had a part time job in the ICTML project as a resource teacher, both for didacticians during planning and accomplishing the workshops and to support teachers in the project. A school team with the three teachers and two didacticians, Aud and I, was established already the first autumn of the project where the teachers had an aim of developing a bank of ICT resources for mathematics teaching at their school. For a long period I planned to design my study with two cases. The second case; "Design and use of own computer software tasks" considered how this team with teachers and didacticians planned, designed, orchestrated use of the tasks in teaching and talked about experience in using computer software tasks in mathematics teaching. Although this case was excluded as a case in this thesis, it was central throughout my data collection which included Austpark, Fjellet and Dalen. I also made some analysis of this case but later decided to omit the case from my thesis since I experienced the nature of the cases to be so different. Instead I aimed to deepen the analysis of the case with Jakob, Frode and Trude in the thesis, and possibly return later to the Dalen case.

4.6 Data collection

As indicated in Section 4.3, data collection went alongside my work and role as didactician within the two developmental projects. In Section 4.6.1, I refer to my research questions and stages in my data collection where I aimed to collect data to address these questions. Section 4.6.2

discusses more specifically how and what kinds of data I collected. In Section 4.6.3 I describe the extent of the data collected and I provide a table (4.3) to characterise and give an overview of these data.

4.6.1 Collection of data to address research questions

In my study I see the data collection as a process where I define *three* stages. Since the field work was accomplished within two developmental projects, the *first* stage involving preparation for data collection by establishing written permissions. An available drive on UiA's server for saving data was already established when I started my study. Data was supposed to be saved on this drive on the server in order to be shared with colleagues in the didactician teams at UiA. The *second* stage was collection of data in workshops at UiA, to start visiting the teachers at their schools, have meetings with the teachers and visit their classes several times in order to get to know the students and the teachers and vice versa. This stage included the constitution of a community of teachers and didacticians in the projects as part of workshop sessions and school team meetings. What I denote as the *third* stage was when I started, on a more regular basis, to make audio and video recordings from visits in Jakob, Frode and Trude's classes and from conversations, school team meetings and interviews with the teachers. The regularity in this stage was initiated by my consciousness of a case with the three teachers evolving during autumn 2005. I experienced that the case helped me in:

- orienting my data collection;
- the analysis process;
- sorting my findings, conclusions and implications.

These experiences are in accordance with claims by Yin who emphasises that a case study "benefits from the prior development of theoretical propositions to guide data collection and analysis" (Yin, 1994, p. 13). At an early stage of my Ph.D. study I started to develop my research questions and to consider a theoretical framework for my research study. I decided to focus on teachers and their use of computer software, and how they expressed their experience with use of the software in mathematics teaching. At first I studied data from workshops, my first computer lab visits at the schools in the ICTML project and school team meetings. I consider this phase of my work to be a start of my *processing* of data. The phase was basically a brainstorm of ideas, inspired by literature studies emphasising teacher perspective such as Goos et al (2003) and Hennessy et al. (2005) quoted in Chapter 2. I started to consider the content of observed events and the two cases described in Section 4.4 evolved.

In this thesis I have outlined a difference between teachers' *implementation* and orchestration of Cabri-*use* (see Chapter 2, p. 27). Implementation of Cabri is considered as a process *leading up* to the three teachers' orchestration of Cabri-use in mathematics teaching. Thus, the analytical approach is based on *teachers' implementation* and orchestration of *Cabri-use* in teaching as *units of analysis* as evident from my research question which I introduced in Section 1.3:

1) *With what motives and goals do teachers at Grade 8 implement and orchestrate Cabri-use in mathematics teaching?*
2) *What characterises teachers' initial orchestrations of Cabri-use in mathematics teaching at Grade 8?*

I argue that in order to answer the research questions I needed a two-fold approach to data collection: I had to observe the teachers in the classroom and/or computer lab, and listen to teachers' voices about their teaching to illuminate their motives for implementation of Cabri and their goals energising their actions and orchestration of Cabri-use in teaching. I end this chapter with Section 4.7.4 where I introduce how the theoretical framework is utilised in analysis of the collected data and contribute to answer my research questions.

4.6.2 What kinds of data were collected and how

The significance of *my aims as a researcher* is important to express when considering how and what kinds of data I collected. For example, based on my interest in teachers' emphases in their orchestrations of computer software use in teaching, I quickly directed the video camera upfront to the teachers and the video screen in front of the room if the teacher decided to have a plenary session with computer software. Hence, my behaviour in the field could by *no means* be described as totally *neutral* which neither was my intention. The teachers *knew* quite well that an aim for my personal research study was teachers' implementation of computer software in teaching although I argued many times that my interests also included more general concerns about mathematics teaching and working as a team of teachers and didacticians. As already brought up, this openness and role as didactician could result in comments from teachers in the way they believed I would *like them* to say things or *casual* replies when the teachers were asked to consider things (see Section 4.1.2, p. 90). However, I argue that my impression was that the teachers experienced the conversations as meaningful both when they included references to computer software use in mathematics teaching and not. I believe the fact that all the three teachers in my case participated in the LCM project, which did not have the particular emphasis on use of computer software as the ICTML project had, strengthens this statement. However, their awareness of my main research interest should by no means be hidden away as a "price to pay" for openness and the co-learning principle.

The evolution of the case (see Section 4.2.2) energised my data collection and helped me both in orienting my data collection and also in my processing of data. I went more regularly to these schools and the three teachers, and I made many observations at the computer labs and had conversations with the teachers. In my car on the way back to UiA from my visits in schools, I usually recorded on audio my immediate comments to what I had observed. I tried to write down notes from the visits immediately after returning to UiA or when I eventually considered the event. The audio with my personal comments was considered alongside notes, audio- and/or video recordings from the lesson or the meeting in schools when I afterwards wrote the notes. The notes helped me in my later treatment of data (see Section 4.7.1) by registering things observed which I knew would be difficult to grasp with audio or video from teaching, meetings and conversations.

The possibility to have brief *conversations* (see Section 4.3.1) before and/or after the lessons varied. Each time I visited Trude we had small conversations occurring immediately after the lessons. Because of the time schedule at Austpark, there were seldom times for such brief conversations after the lessons in Frode and Jakob's classes. There I usually only had some quick conversations on the way in and out of the classroom or computer lab.

Collection of data through *interviews* was arranged round some premade questions or points on a list. Before commenting on these arrangements, the interviews included in my case are:

1. An end of Cabri-use focus group interview with Jakob, Frode and Harald at Austpark. This interview is later denoted *the end of Cabri-use interview* at Austpark.
2. The LCM/ICTML focus group interview at Austpark with the five teacher and the vice principal at Austpark.
3. The LCM/ICTML focus group interview at Fjellet with Markus and a teacher at Grade 2 (Trude was not teaching at Fjellet at the time when the LCM/ICTML focus group interview was conducted).
4. An end of ICTML project interview with Aud, the project leader in the ICTML project, discussing experience related to didacticians support of the teachers in the project.

In the three interviews with teachers, I wanted them to share their experience from teaching and pay attention to why they taught the way they did. This provided me with some insights to their motives and goals energising their use of computer software in mathematics teaching. In the end of Cabri-use interview at Austpark, which occurred few weeks after their teaching with Cabri in 2006, the teachers talked about their experience of implementation and orchestration of Cabri-use in teaching. The LCM/ICTML focus group interviews had a broader scope of focuses discussing development in mathematics teaching and teachers' and the leader's experience from participation in the projects which at the time of the interview had lasted one and three quarter years. In the interview with Aud (see point 4 in the list above), didacticians' support of teachers in the ICTML project was discussed and particularly related to efforts made by didacticians ahead of teachers' implementation of Cabri at Austpark and Fjellet. Thus as a difference, the latter interview and the first mentioned interview had a more specific theme to be discussed than the LCM/ICTML interviews.

As mentioned above, in all the interviews pre-made questions guided the interviews. During the end of Cabri-use interview, I had a list with three main elements I wanted or hoped would be discussed during the interview. This was related to their planning and implementation of Cabri, their role as teachers in Cabri-lessons, and their experience from teaching including students' achievements. I had prepared some check-points to each element and phrased some follow-up questions to ensure that they were discussed if the teachers did not address them. At the start of the interview I said to the teachers that I would welcome any contributions they found appropriate in respect to the theme of the interview as a follow up from their Cabri-lessons. A similar approach in structuring the interview and my role as interviewer was utilised in planning and accomplishing the interview with Aud. In the LCM/ICTML focus group interview, as the interviewer, I addressed more strictly a list with 12 questions shared by didacticians ahead of the interviews at each school. The questions are available in Appendix 4. The questions dealt with why the schools wanted to participate in the projects, what they had found valuable, difficult and problematic, questions about work in school teams, implementation in classrooms, the relevance of the concepts inquiry and community and roles in the projects. Thus, the LCM/ICTML interview was *more structured* than the two others since altogether 12 pre-made questions were phrased explicitly during the interview. Below I briefly consider the interviews in relation to a model with two dimensions of qualitative interviews presented by Rubin and Rubin (2005):

Table 4.2: Based on Table 1.1 in Rubin & Rubin (2005, p. 5)

	Narrowly Focused Scope	In-Between	Broadly Focused Scope
Focused Mainly on Meanings and Frameworks	**Concept clarification**	**Theory elaboration**	**Ethnographic interpretation**
In-Between	**Exit interview**	**Oral histories Organizational culture**	**Life history**
Focused Mainly on Events and Processes	**Investigative interviewing**	**Action research Evaluation research**	**Elaborated case studies**

I argue that the end of Cabri-use interview and the interview with Aud (see Point 1 and 4 in the list presented earlier in this section, p. 108) best can be characterised as investigative interviews while the LCM/ICTML interview had a more action research/evaluation research emphasis. This difference refers to the more narrowly focused scope in two of the interviews while I argue that all four interviews mostly emphasised events and processes using Rubin and Rubin (2005) terms in the figure above.

Use of questionnaires and reporting schemes given to the teachers in the projects are ways of collecting data that I have considered but used only to a very limited extent. Teachers in the project had been asked by didacticians to fill in the scheme's 4 columns with information: date for teaching with computer software in mathematics, content of lesson, what kinds of software used and brief experience from use of the tool in lessons. Appendix 5a) presents the layout of the scheme, and contains the details filled in by Trude which she handed in to Aud late in March 2006. These schemes mainly helped me in getting an overview of the extent of teachers' use of computer software. I have also gathered background material such as copy of handouts to students from teachers. These handouts include copies of tests and students' solutions files from tests in Cabri, teaching packages used when teaching with Cabri and a survey designed by two of the teachers. Copies of e-mails and letters have also served as an effective way to gather data.

4.6.3 The extent of data in my case study

In my case study altogether 44 events are included. The 44 events comprise sessions in classrooms and computer labs, workshops, meetings in the team of didacticians, school team meetings, conversations with teachers, interviews, conference presentation, copy of e-mails, a letter to Austpark and a book chapter. In addition, copies of materials used in teaching and the projects contribute as data in my case study. The latter were exemplified in the previous section and are attached as appendices.

The first event included in the case is the third workshop in the ICTML project, denoted ICTML Workshop 3, occurring in January 2005. The final event in the case is the interview with Aud three years later in January 2008. A majority of the events, 23, are from the period from January to March 2006 when the three teachers for the first time used Cabri in their teaching. Each event is described briefly in Appendix 1 and numbered chronologically (1-44). In Appendix 1, the total length of each event in minutes, available types of data (audio, video, notes, copy of worksheets etc) and whether or not 'data reductions' and 'transcriptions' exist and their extent are indicated. The role of data reductions and transcriptions are commented on in Section 4.7.1. Below, in Table 4.3, I present a comparison sketch of the two schools and the events which constitute the case.

Table 4.3: Characteristics and overview of different events in the case study

	Austpark	**Fjellet**
Teachers:	Jakob and Frode	Trude
Time of Cabri-teaching:	January-February 2006. In addition review in May ahead of the examination.	January-March 2006
Extent of Cabri-lessons:	8-9 times 45 minutes and two tests with Cabri	6 times 45 minutes
Classroom and computer lab visits:	Events 14, 15, 17, 18, 19, 24, 25, 26, 28, 29, 36, 37, 40	Events 22, 32
Conversations related to computer lab visits:	Events 20, 27	Events 23, 33
School team meetings:	Events 6, 9, 12, 13	Events 5, 10
Interviews:	Events 31, 35, 43, 44	Events 34, 43, 44
Workshop sessions at UiA:	Events 1, 2, 16, 21, 30, 39	Events 1, 2, 16, 21, 30
E-mail, letter, conference contribution, KUL meetings, book chapter:	Events 3, 4, 7, 8, 11, 38, 41, 42	Events 3, 11, 43
Different kinds of additional resources available and included in Appendices:	Copy of worksheets (Appendix 2), Cabri-survey (Appendix 5b) and Cabri-test (Appendix 5c).	Copy of reporting scheme from Trude (see Appendix 5a)
Other teachers contributing to the case:	Gunnar, Harald, Elise and Eivind. The principal and vice principal	Markus, Ludvig and the principal
Didacticians	Aud, Eli, Ingvald, Otto	Aud, Ingvald, Otto

The three teachers' classes had between 20-25 students. In the table, I have indicated that each student in Trude's class had 6 times 45 minutes with Cabri. Altogether Trude had 12 times 45 minutes with Cabri in her class but only half of her class used Cabri in each lesson. In Jakob's class and Frode's two classes, the numbers of Cabri-lessons for each student were 8-9 times 45 minutes including review of two Cabri-tests. In addition, Jakob and Frode's students accomplished the two Cabri-tests and use of Cabri was referred to in lessons with compasses.

It is evident from the overview in Table 4.3 that the majority of the events are related to Jakob and Frode at Austpark. Data contributing to the analysis in Chapters 5 and 6 is dominated by the same teachers and school. However, I still argue that an analysis of Trude's contribution to the case was crucial offering a possibility to compare implementation and orchestration of Cabri-use for three teachers at two schools. The analysis would have benefited from having a broader range of data related to Trude. One reason for the limited amount of data was that didacticians were first informed about her implementation of Cabri after she had accomplished her first lesson in January 2006. A second reason was Trude's break from teaching and end of project participation in March 2006. This was ahead of her final planned Cabri-lesson and before my planned end of Cabri-use interview with Trude. Her break from teaching also meant that Trude neither participated in Fjellet's conference presentation nor focus group interview occurring after the start of her break.

The possibility to include different kinds of sessions in the data collection, as listed in Table 4.3, gave me good possibilities for triangulation. For example, I observed how the teachers in their orchestrations emphasised students' development of successful *techniques in Cabri* (see Section 6.1, p. 192) which I triangulated with their comments concerning their orchestrations and how they expressed students' lack of utilising Cabri as an issue.

4.7 Introduction to data analysis

In this section I give an introduction to the data analysis in Chapters 5 and 6. I focus on the gradually more systematic processing of data (4.7.1) where 'data reductions' and 'transcriptions' became helpful tools. Section 4.7.2 presents my development of codes and how coding was utilised in processing of data. Presentation of transcripts and how they were shaped for the thesis is commented in Section 4.7.3. I end the chapter with Section 4.7.4 which contains an overall perspective to the analysis chapters by considering briefly how data from the case study contributed to the analysis.

4.7.1 Processing of data

In Section 4.6 my data collection and the 44 events in my case study were outlined. Initially I made brief overviews of each event as indicated in Appendix 1, and I wrote notes after each visit to the schools where parts of the sessions usually were recorded on audio or video. I consider these notes and overviews as my *first* phase in processing of data. My *second* phase was more systematic and involved making 'data reductions' of events. To make data reductions of observed events had been suggested by didacticians in the LCM project. A *data reduction* was supposed to contain time, summarised content and headlines as three columns in a sheet. In Appendix 6c, I illustrate with an example of a data reduction from part of a group session in LCM Workshop 10. Data reductions helped me to maintain overview of content in events, were helpful in the coding process (see Section 4.7.2) and in selection of utterances to include in the analysis.

The episodes presented in this thesis are *transcribed utterances*, either produced by myself, other didacticians or one of the secretaries who have been employed in the projects. In Section 4.7.3, I outline how transcripts are presented in the thesis. Ahead of the design of transcriptions from an event, I listened or watched an audio or video recording of an event many time and produced a data reduction and I very carefully picked out certain parts of the event I considered worthwhile for my research study. The selection of data was made based on personal interpretation, what I denote as a pre-analysis of collected data, emphasising inclusion of all data that I interpreted that contributed to my research. These interpretations were influenced by considerations mentioned earlier in the thesis, in particular the research questions which were revised alongside my data collection, reading of literature and my elaboration of a theoretical framework and research design.

I *arranged data in maps* sorted on schools and teachers, which I experienced as a purposeful tool to give myself an overview of collected data, data reductions and eventually transcribed utterances. As an example, the map for Jakob is attached as Appendix 6a. In the maps, data and type of event, brief description of content and main elements (which refers to codes commented in the next section) and available types of material (audio, video etc) are indicated. Such maps sorted on individual teachers like Jakob were considered together with events from sessions *not* including Jakob. For example, when I studied Jakob and Frode's implementation of Cabri, also contributions from Gunnar and Harald ahead of Jakob's entrance in the projects have been considered. The case considering Cabri was reviewed in this phase of my processing of data to emphasis teachers' implementation and orchestration of Cabri-use and given the title: *Teachers' implementation and orchestration of Cabri-use in mathematics teaching.*

4.7.2 A coding-process

Above I referred to interpretations of collected data as crucial in the gradual development of the case in my study and processing of data. Interpretation was highlighted already in Section 4.1 where I argued for working as an *interpretive researcher studying and supporting development in mathematics teaching.* Interpretation is by Flick (1998) denoted as *theoretical coding*:

> Interpretation is the anchoring point for making decisions about which data or cases to integrate next in the analysis and how or with which methods they should be collected (Flick, 1998, p. 179).

The mentioned maps of data were sorted in different ways, on schools and teachers, kinds of events, such as computer lab visits and workshop sessions, and the kinds of tools that were used such as Excel, Cabri and compasses. Eventually these maps also included what I consider as being codes, at the start some brief headlines indicating the content of the events. These first codes evolved based on the content of the events and the content's interplay with the research questions. An example: Research Question 2 emphasises characteristics of teachers' orchestrations of Cabri use. When the teachers reported from their teaching with Cabri in workshops, they expressed several times how they experienced a need for assisting their students to *use Cabri accurately*. Observations in Jakob and Frode's lessons exemplified how the teachers, typically in a step by step way, guided their students to accomplish a construction. Appendix 6b gives an overview of some codes I had developed until June 2006, where teachers' emphasis in the example above was coded as *tool skills*.

Now I briefly want to relate my coding process to Flick's (1998) description of theoretical coding where he argues that interpretation is a three stage process: *open coding*; *axial coding*; and *selective coding*. Based on his description, open coding was typical for my initial work with data and transcripts where expressions in the events were classified based on the content. I developed a number of disconnected codes relevant to the research questions. I noticed teachers' comments about issues like time, own lack of skills and experience in using computer software, concerns about students' inaccurate use of Cabri, and expressed importance of designing tests and have available good tasks. Three of my codes were *time, lack of access* and *students' tool skills*. All the codes, numbered 1-16, are presented in Appendix 6b. The codes are not merely expression in the events but codes which reflected my research questions.

Adjustment of codes in new categories, like my categorisation of teachers' comments on students' inaccurate use of Cabri as a focus on students' tool skills, seems close to what Flick denotes as the axial coding. In what I regard as my axial coding process, categories of data were sorted for the analysis, and I considered more extensively how the data and the codes could contribute to address the research questions. Data coded *time* and *lack of access* were categorised as highlighting issues in teachers' implementation process, and they are indicated as codes in the category named a) in Appendix 6b. This categorisation process with codes also stimulated further development and refinement of the research questions.

In accordance with my focus on teachers' *implementation* and *orchestration* of *Cabri-use*, I developed two main categories of codes named a) and b) (see Appendix 6b. The two categories are dominated by respectively teachers' concerns about issues in the implementation process, and students' lack of utilising the potential of Cabri and how the teachers responded to this. I also considered relationships between these two categories of codes since teachers in sessions often paid attention to both implementation and their use of Cabri in teaching. Utterances close in time or the very same utterance often contained data which was coded in both categories, such as Jakob and Frode's design and use of Cabri-tests in all classes at Grade 8 which worked as a criterion for implementation of Cabri and energised their orchestration of Cabri-use in teaching. The development of new categories of codes and considering relations, are according to Flick also typical for the selective coding process as a further step from the axial coding.

The development of codes, evolving based on study of my earliest made transcripts, in fact helped me afterwards when I made data reductions of new events, in selecting which parts I wanted to transcribe and in orienting the coding of new transcripts. In the data reductions, the right column with brief description of the content includes use of some of the codes indicated in Appendix 6b. In Chapters 5 and 6, altogether 15 episodes from this data reduced session are considered in the analyses. One of these episodes is presented already in the coming section (4.7.3) to illustrate how I present transcripts in this thesis.

An obvious limitation with my coding process is that the interpretation process with development of codes obviously could have been done in many ways. The same data could "produce" many different emphases based on different aims of the research. In this thesis I try to remain open to the reader and include descriptions and short comments to each of the events in the case study and how I processed with the data (Appendices 1 and 6). The maps and codes were very helpful in the early phase of development of the analysis chapter. However, the coding went on alongside the writing where analytical findings helped me in reorganising sections and chapters. Consequently, the end of the coding process is implicitly visible in the design of Chapters 5 and 6 and their different sections.

4.7.3 Presentation of transcripts in the analysis

Appendix 7 is an overview of data excerpts used in Chapters 5 and 6 with reference to events in the case study listed in Appendix 1. Below I offer an example indicating how I present transcripts in the thesis. Except for some meetings and parts of workshops where English was used, other sessions were held in the Norwegian language. Since the thesis is written in English, I present both the original transcript from transcription of events and an English translation made by myself. Utterances, abbreviated Ut, and episodes, which are selections of subsequent utterances, are numbered chronologically. The episode below with three utterances is presented in the analysis (see Section 6.1.5, p. 234).

Ut	Who	What is said (translation)	What is said (original)
384	Jakob	…. So, those worksheets, their nature are not very investigative, they are fairly, really focused on letting the students trying out the tool a bit [and to achieve]	… Så de de kursarkene de er de er ikke sånn veldig sånn veldig utforskende av natur de er veldig sånn egentlig fokusert på å få prøvd verktøyet litte grann [og få]

385	Trude	[Yes]	[Ja]
386	Jakob	So I think after a while, when they have managed to accomplish and learnt the tool a bit, then they will be ready to use it a bit more investigatively.	Så jeg tror nok etter hvert når de har kommet seg igjennom og lært verktøyet litt så kan man nok begynne å ta det i bruk litt mer utforskende virksomhet da.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 13

The transcripts and translation of the transcripts have been shaped by using the LCM and ICTML transcription keys developed in the projects (see Appendix 6e). During the analysis, as suggested in the projects, I spent much time with the raw material, either an audio or video recording and in this process elaborated further the transcripts. I also made some few simplifications in the transcripts presented in this thesis aiming to lightening the reading. As an example, immediate repeats such as "I, I wonder if, if it would …" have been simplified to "I wonder if it would…" except for a few situations where I have interpreted that such repeats contribute and for example indicated uncertainty. In accordance with the LCM and ICTML transcription keys I have included brackets with italics text to help the reader to follow what is being said. For example when a person talks about "it" I might have written (*refers to Cabri*) if that is the case.

4.7.4 Entrance to analysis in Chapters 5 and 6

In Section 4.6.1, I argued for a two-fold approach to data collection in order to answer my research questions. I end this chapter by indicating how I apply the theoretical framework in Chapter 3 analysis of data in the coming two chapters:

1. Classroom and computer lab observations in order to illuminate teachers' orchestrations of Cabri-use in teaching. The analysis of teachers' orchestration includes attention to their focuses in teaching, style of teaching and their teaching operations during the lessons. Activity theory proposes that teachers' *actions* and *operations* are energised by their *goals* within *conditions* in teaching, the second and third level offered by Leont'ev. In addition I utilise the *instrumental approach* (Trouche) concerning how *teachers' orchestrations* support students' *instrumental genesis* of Cabri. Data from classrooms and computer labs are the main sources of data for the analysis in Chapter 6.
2. The other sources of data, where the teachers discuss and talk about their teaching and plans for teaching, is helpful to illuminate teachers' *motives* for *activity* which include use of computer software applying the third generation of *intersecting activity systems* offered by Engeström. When the teachers talk about their teaching, their emphases indicate what they wanted to achieve with

their teaching indicating their *goals* energising *actions* in teaching. Thus, this source of data both relates to the upper and second level offered by Leont'ev in *activity theory*. Informal conversations with the teachers, often on the way to or away from lessons in computer labs or classrooms, interviews, school team meetings and workshops at UiA are the main sources of data for the analysis in Chapter 5 as well as supporting the analysis in Chapter 6.

5 Teachers' implementation of Cabri

This thesis employs an analytical approach in which teachers' implementation and orchestration of Cabri use in teaching is the *unit of analysis*. In this chapter, I present my analysis of Jakob, Frode and Trude's implementation of Cabri in mathematics teaching at their schools utilising activity theory in the analysis. Teachers' orchestrations of students' use of Cabri in their teaching is considered in Chapter 6. The relation between *implementation* as a developmental process leading up to teachers' orchestrations of Cabri-*use* in mathematics teaching was considered in the introduction to Chapter 2 (see p.27):

> I consider a teacher's *implementation* of Cabri as a developmental process. I analyse the process of development in teaching from teachers' first introduction to Cabri in workshops at UiA where they started to discuss possible use and what they wanted to achieve with use of Cabri in teaching. In follow up workshops and in school team meetings, the teachers started to address *issues* they needed to overcome in order to have a successful use of Cabri in teaching. Thus, implementation of Cabri was a process leading up to the three teachers' orchestration of Cabri-use in mathematics teaching, but implementation and use do indeed also overlap. Teachers might start to use Cabri despite having faced issues in the implementation process. One such example is the issue of students' lack of access to Cabri at home raised by one of the teachers in my study (discussed in Chapter 5). When I refer to *use*, or to be more precise teachers' *orchestration* of Cabri-*use* in teaching, it is the practice in classrooms and computer labs which is at the stake. Through teachers implementation process decisions to use Cabri and adaptations to their school settings were made. However, I consider teachers' *arrangements* for use of Cabri such as organisation of students and use of teaching packages as being part of their orchestration of Cabri-use.

Thus, when I in this chapter refer to teachers' implementation of Cabri I emphasise the process from didacticians' introduction of Cabri in workshops, teachers' comments during the workshops, their decision to use Cabri and adoptions in order to be able to use Cabri. When I in Chapter 6 analyse teachers' orchestration of Cabri-use in teaching, it involves their arrangements for use of Cabri as well as their teaching and considerations to their teaching.

In the analysis of teachers' implementation of Cabri in this chapter, I utilise *activity theory* to discuss teachers' *motives* and partly their *goals* for implementation of Cabri. In Chapter 3 I argued that motives are oriented to *shared objects* and *desired outcomes* (see Section 3.1.3, p. 65) within activity systems and accomplished in teaching energised by teachers' and students' *goals*. In the analysis in this chapter, *three intersecting activity systems* are considered. The activity systems were listed in Chapter 3 and are further outlined in Section 5.1.

In Section 5.2, I present findings indicating how teachers' participation in the ICTML project influenced their implementation of Cabri. Section 5.2.1 presents how didacticians, in workshops, meetings and other sessions, offered different kinds of support for the teachers in which Otto had a crucial role. Otto's role in workshops, meetings and as a resource teacher for the teachers in the projects has already been discussed (see Section 4.5, p. 105). Sections 5.2.2 and 5.2.3 emphasise teachers' reactions to and interpretations of the support by didacticians. Section 5.3 contains an activity theory analysis of the external support by didacticians and indicates how the support contributed to teachers' motives for implementation of Cabri in their teaching.

In Sections 5.4, 5.5 and 5.6, I present findings and theoretical analysis of teachers' motives for implementation of Cabri. This is done by analysing their comments indicating *reasons* for their implementation of Cabri, and by considering the different *issues* they raised and how they managed to cope with these issues. I also relate these issues to internal elements and the external influence illuminated in the activity theory analysis. By *external* I refer to statements in the curriculum and proposed actions in the developmental projects where didacticians had a central role. The *internal* refers to personal and institutional elements at their school. Building on an activity theory theoretical perspective, elaborated in Chapter 3, I offer *intersecting activity systems* as an analytical tool emphasising *tensions*, *contradictions* and *expansions* to discuss both teachers' motives and indication of teachers' goals. Teachers' goals are considered further in Section 6.3.2 when analysing teachers' orchestrations of Cabri-use in teaching.

5.1 Three activity systems considered in the analysis

To support the analysis of teachers' implementation of Cabri, I have introduced three kinds of activity systems (see Section 3.1.6, p. 66):

a) *The KUL activity system* composed of didacticians and teachers which proposes objects and actions for the school activity systems and teaching activity systems.
b) *The school activity system* at each school composed of teachers and school leaders which proposes objects and actions for *each teacher's teaching activity system*.
c) *The teaching activity systems* typically in Norway composed of one teacher and 20-30 students.

In accordance with aims in the LCM and ICTML projects (see Section 1.2), *improved learning and development in mathematics teaching* were *aims* for the KUL activity system at an overall level, and in particular *utilising computer software* (and other kinds of ICT tools) for the ICTML project. A desired *outcome* was *collaboration* and creation of *learning communities*, which in the ICTML project was related to *implementation* and *use* of *computer software*. Using the *three level* model of Leont'ev (elaborated in Section 3.1.2, p. 61), these aims and desired outcomes served as *motives* for the *activity* in the KUL activity system. In the analysis in Section 5.3, I give a further elaboration of the KUL activity system.

In the *school activity system,* the superior motive of students' learning of mathematics is given through the National Curriculum. Teachers as part of the school culture have the responsibility to turn these motives for students' learning of mathematics, serving as objects in the activity, into *goals* for *actions* within their *teaching activity systems*. The relationship between goals which energise actions relates to the *second* level in Leont'ev's model. Teachers' goals also energise their orchestrations and observable 'teaching operations' (see Section 2.3.2, p. 49) in teaching which relates to the *third* level proposed by Leont'ev. The latter is considered in the analysis in Chapter 6.

5.2 External support by didacticians

In Chapter 4 I indicated that three teachers at Fjellet and five teachers at Austpark participated in the projects. Although the case study considers three of these teachers' implementation of Cabri, the five other teachers also contributed to the implementation process as evident in this chapter. During the ICTML project, didacticians *supported* the teachers in their development process of implementing DGS[19] such as Cabri in their mathematics teaching:

- In ICTML Workshop 3, Cabri was introduced to teachers and the teachers were challenged about their readiness for use of Cabri in teaching.
- Didacticians repeated an emphasis on Cabri in a number of workshops afterwards where they challenged the teachers to report from their implementation and use of computer software in teaching.
- Didacticians requested school team meetings to discuss implementation of computer software and inquiry in mathematics teaching.
- Didacticians in the ICTML project offered assistance by Otto as a resource in teachers' implementation process with computer software tools in mathematics teaching.
- Didacticians repeated the emphasis on computer software implementation by asking the teachers to present their experiences for others such as in a conference at UiA.

In Section 5.2.1 I present how didacticians in workshops at UiA gave initial support of implementation of Cabri by introducing Cabri and ask-

[19] DGS as an abbreviation for a dynamic geometry software package such as Cabri was introduced on page 32.

ing whether the teachers felt ready to implement Cabri in teaching. Half a year after their first introduction of the tool, didacticians requested meetings to discuss implementation of Cabri and other kinds of computer software at three of four schools in the ICTML project. The fourth school, Dalen, was as mentioned in Chapter 4 in a different developmental process with ongoing planned work for computer software use. In the case study with teachers from two of these three schools, I consider the requested meetings as the start of a second phase of didacticians' support of teachers in the implementation phase of Cabri. This second phase and the teachers' at Austpark and Fjellet's reactions and interpretations of the support are considered in Sections 5.2.2 and 5.2.3. Section 5.2.4 includes a brief summary of the analytical findings in Sections 5.2.1, 5.2.2 and 5.2.3. In Section 5.3, I offer analysis of these findings utilising *activity theory* to consider how didacticians' support contributed to teachers' motives for implementation of Cabri. In the analysis I utilise the three kinds of *activity systems* presented in Section 5.1.

In this section and later sections, *support* and *challenge* are used as terms to describe didacticians' actions when working with teachers. I use these terms to emphasise how didacticians worked to address aims in the developmental projects which were collaboration and development of learning communities at a general level and teachers' utilisation of computer software with inquiry in mathematics teaching as a specific aim in the ICTML project. Different kinds of support were mentioned in the previous paragraph and challenges were made by for example asking a question like "Are you ready to use Cabri in your teaching?"

5.2.1 Initial support by didacticians in workshops

In ICTML Workshop 3 on the 26th of January 2005 at UiA, the teachers in the project were introduced to Cabri as a DGS package. The workshop had the following sketch: After being introduced to Cabri in a plenary session led by Otto and Aud, the teachers worked with Cabri in a computer lab session interrupted by two brief plenary contributions by Otto. The duration was approximately two hours including a fifteen minutes break. In addition, the workshop ended with a 25 minutes session where the teachers, in a plenary, shared their immediate comments after working with Cabri. In this final session, considered below, the teachers were asked to give *feedback* to the content of the workshop and challenged to *consider implementation* of Cabri in their mathematics teaching.

In this final session, the teachers emphasised possibilities and obstacles for a potential implementation of Cabri in their mathematics teaching mentioning time as one issue. These more internal elements will be considered in Section 5.3. But the teachers also gave some feedback to the nature of the workshop. Harald at Austpark expressed gratitude to the support from UiA in being *introduced to Cabri*. In the episode below, he continued arguing *why* he particularly appreciated a *task* which was based on a practical application of mathematics: The Road Company.

Ut	Who	What is said (translation)	What is said (original)
116	Harald	[So, so]	[Så, så]
117	Harald	it is	er det jo
118	Harald	[always fun to]	[alltid gøy å]
119	Otto	[Or one has to (…)]	[Eller så må (…)]
120	Harald	yes, it is always fun to try tasks such as the first you presented for us with the Road Company; so some hints to such (*he probably refers to tasks*) which we can develop further ourselves and help us to develop ideas and	ja, så er det jo alltid gøy å prøve noen sånne oppgaver slik som den første du viste der med vegvesenet; altså litt sånn tips til sånne (*refererer trolig til og oppgaver*) som vi kan videreutvikle selv og komme på ideer og
121	Harald	[so on]	[sånt]
122	Some	[Mm]	[Mm]
123	Harald	That is brilliant!	Det er topp!

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video, Episode 1

Presentation of transcripts in this thesis, such as the example above, is explained in Section 4.7.3 (see p. 115). Table 4.3 (see p. 111) presents an overview of events in the case study, referring to Appendix 1 which includes a list of events sorted chronologically by date. The numbered episode, such as Episode 1 above, refers to the list of episodes from each event presented in the thesis (see Appendix 7). Episodes are parts of an event and are numbered relative to their event.

Near the end of the workshop, Aud challenged teachers about potential *use* of Cabri in teaching by referring to *inquiry* and *investigative tasks* which had been suggested more broadly by didacticians in the LCM project. This challenge from Aud is presented in utterance 189 below: "…how can we get some proper investigative tasks or inquiry and such out of this". The immediate response came from Markus at Fjellet who gave feedback to the way of working in the workshop which he expressed as being valuable. He pointed to a need for what he denoted as *technical assistance* which seems to be linked to development in using Cabri. Like Harald he emphasised the benefit of *sharing* and *access* to *good tasks*, using the term "investigative tasks" as used by Aud:

Ut	Who	What is said (translation)	What is said (original)
189	Aud	… How can we get some proper investigative tasks or inquiry out of this? In what ways, sometimes you have some students who start to formulate questions and really start to dig into this. What can we do to succeed in this? Can this software be used?	…Hvordan kan vi få noe skikkelig utforskningsoppgaver eller inquiry ut av dette? Hvordan, du har jo av og til elever som selv begynner å stille spørsmål og grave i dette. Hva skal vi gjøre for å få til det? Kan dette verktøyet brukes?
190	Markus	You asked if there are more we need to learn and obviously there are much more to learn technically. I think it is a very nice way to work like we have done now.	Du spurte i sted om det var noe mer som vi hadde å lære og selvfølgelig er det mye av det der tekniske. Jeg synes det er en veldig flott måte og så jobbe på sånn som vi har gjort nå.
191	Aud	Mm.	Mm.
192	Markus	To have good assisters like we have here, which guides us in our work with the tool, and like so. I think that is really great and is really well applied time. I would have liked that if we came back we could have had even more emphasis on ideas to such, such investigative tasks. And that we simply, each of us, consider ideas on our own according to the grade we teach, well…	Ha gode støttespillere som er her og peker hvor en skal ta seg fram og litt sånn. Det synes jeg er kjempeflott og det er utrolig godt anvendt tid. Jeg kunne tenke meg at hvis vi kom tilbake igjen at vi at vi så enda mer på litt sånn litt sånn innspill til utforskningsoppgaver. Og så at vi hadde det rett og slett litt i bakhodet hver enkelt, litte grann på hver hvert vårt trinn altså….

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video, Episode 2

Thus, Markus did not directly answer Aud's question in utterance 189. However a minute later, in utterance 219, Aud asked Trude whether she felt *ready to use* Cabri in teaching. Trude's reply to Aud's explicitly directed question was to emphasise *priority on Cabri* as a necessary *condition* in order to be able to implement and use Cabri in teaching:

Ut	Who	What is said (translation)	What is said (original)
219	Aud	Yes. Have you got enough input to dare to use it in your class?	Ja. Har du fått nok til at du våger å bruke det i klassen?
220	Trude	So far	Så langt
221	Aud	[Yes]	[Ja]
222	Trude	I have come	er jeg kommet
223	Aud	Yes	Ja
224	Trude	But I think about reserving some time like we do now	Men jeg tenker også det å rydde tid sånn som vi gjør nå.
225	Aud	Mm.	Mm.
226	Trude	For me it is of necessity if not I will not manage it.	For meg er det ellers får jeg ikke gjort det.

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video, Episode 3

Thus, while Aud in her questions focused on teachers' readiness for *use* of Cabri, Trude in her reply seemed to be concerned about a preparatory phase in her *implementation* process as well as the use of Cabri in teaching.

Cabri was also the main focus in the following ICTML workshop in April 2005. However, despite efforts to stimulate implementation and use of Cabri in mathematics teaching in these two workshops and a few school team meetings at the schools, none of the teachers at Austpark and Fjellet implemented Cabri during the spring and early autumn 2005. Thus, didacticians started to consider how they could support development in teaching better. Section 5.2.2 contains analysis of how didacticians wanted to support teachers at their schools and how didacticians considered the outcomes of this. Sections 5.2.3 and 5.2.4 pay attention to the particular support at Austpark and Fjellet and teachers' comments and reactions of the support.

5.2.2 Didacticians' support of teachers at schools

Didacticians wanted to give teachers time to establish work in school teams and plans for computer software use. However, didacticians in the ICTML project eventually considered the lack of information of what was going on in schools and doubted development in ICT use, based on a few school visits and teachers comments in workshops, to set a need for suggesting more support of teachers in three of the schools. Thus, an e-mail was sent on the 28th of September 2005 to each of these schools, Austpark, Fjellet and Vestpark. The e-mail was sent by Aud, the project leader of the ICTML project, on behalf of a group of didacticians who included herself, Otto and myself. The e-mail requested school team meeting with the teachers and one school leader at each of the schools during autumn 2005. In school team meetings, the project leaders of the two projects had suggested the following participants: the teachers in the project at the school, one of the school leaders and one or several didacticians. In the e-mail, the didacticians indicated two related reasons for suggesting meetings: To offer *better support* to teachers' implementation and use of computer software in mathematics teaching and discuss status quo at the schools. These aspects were described in the following way in the first part in the e-mail before possible dates for school team meetings were suggested:

What is said (translation)	What is said (original)
After the workshop today (*refers to ICTML Workshop 5*), I talked with Otto about how we could support you better in your work with the ICTML project. We wish to come to your school to have a meeting, approximately 1-1,5 hours. It would be fine if one person from the school's administration could participate. From our group Aud, Otto and possibly Ingvald will come. We want to discuss status quo concerning the ICTML project at the school, and further development.	Etter vekstedet idag (*refererer til ICTML Workshop 5*), snakket Otto og jeg om hvordan vi kan støtte dere bedre i arbeidet med IKT prosjektet hos dere. Vi ønsker å komme til skolen for et møte på ca 1 - 1,5 time. Det er fint om en fra skolens administrasjon også kan være med. Fra oss kommer Aud, Otto og muligens Ingvald. Vi ønsker å ta opp status i IKT prosjektet ved skolen, og videre utvikling framover.

Event 3, Sep 28th 2005, Aud, E-mail concerning ICTML, Episode 1

16 days after the e-mail related to the ICTML project was sent to Austpark, Fjellet and Vestpark, another letter to the vice principal at Austpark which addressed issues of the school's participation in the two projects and requested a school team meeting. This letter was sent through post-office service, made and signed by the project leaders of the LCM and ICTML projects Eli and Aud. One school team meeting at each of the three schools were scheduled and held within a month after the e-mail was sent. At Austpark, another school team meeting was held some weeks later based on the request in the letter to the school. The school team meetings at Austpark and Fjellet will be considered in Sections 5.2.3 and 5.2.4 as well as other school team meetings and workshop sessions during the same autumn and the following winter.

On the coming pages, two main questions are considered through analysis of two meetings in the KUL team[20] of didacticians at UiA and an interview with Aud where didacticians' support of teachers in the ICTML project was discussed:

1. What did the didacticians want to achieve with the requested school team meetings?
2. How did the didacticians consider the outcome of these school team meetings?

The content of the letter to Austpark is also considered as well as further comments to the already mentioned e-mail. Thus, data from a total of five events are treated. An overview of these events is presented below in Table 5.1. The numbered events refer to the list of events in the case study described in the overview in Appendix 1.

[20] KUL team meetings were held regularly at UiA. Usually all the didacticians or most of the didacticians in the two projects participated in these meetings.

Table 5.1: List of events considered in the rest of this section (5.2.2)

Event	Date	Type of session
3	28.09.2005	E-mail from didacticians in the ICTML project
4	14.10.2005	Letter to Austpark concerning LCM and ICTML projects
7	27.10.2005	KUL team meeting discussing project commitment
11	01.12.2005	KUL team meeting at UiA about development at schools.
44	05.09.2006	End of ICTML project interview with Aud

In the KUL team meeting on the 27th of October, Aud reported from the three school team meetings requested by the ICTML project which she argued had a positive conclusion in the end. She referred to concerns about lack of ICT use at the three schools and lack of responses to e-mails which had been brought up in the school team meeting. Aud emphasised that an aim of the school team meetings had been to offer the teachers better support in implementation of ICT where Otto was supposed to be a resource:

Ut	Who	What is said (original)
43	Aud	…So, it was a meeting that we wanted to try to help them a little bit more, and also to have Otto visiting them to help them get more started. And also we took up some other problems, some people not giving message back and lack of communication. And I think the schools experienced this fairly positive. …

Event 7, Oct 27th 2005, UiA, KUL team meeting, Audio, Episode 1

Trude also explicitly referred to experience from the meeting at Austpark where she argued that both the teachers and the school leader had emphasised a desire for further participation in both projects. In another KUL meeting five weeks later, the situation at Austpark was discussed. Aud, Eli and I presented for the other didacticians our experience from the two requested school team meetings at the school. The letter (see Event 4) had been central in these school team meetings, and content in the letter is presented below. In the letter, the didacticians did point to *positive* experiences from a couple of visits in lessons held by teachers at Austpark and positive experiences from collaboration with the teachers during workshops at UiA. Concerns about *lack* of *collaboration* among the teachers and the extent of *development* in teaching, connected to the projects, were raised as an issue in the following way:

What is said (translation)	What is said (original)
…It is a matter of us observing too little of your teaching. Separately the teachers have accomplished a bit, but working as a team, which is a central element of the projects, has been insufficient. We really want to continue the contract but there always seem to be obstacles.	… Det blir bare for lite vi ser gjennomført i praksis. Hver og en av lærerne har gjennomført en del, men arbeidet som team, som er et sentralt element i prosjektene, har vært mangelfullt. Vi ønsker virkelig å kunne fullføre kontrakten, men det synes alltid å være hindringer…

Event 4, Oct 14th 2005, Aud/Eli, Letter to Austpark, Episode 1

When didacticians commented the situation at Austpark in a KUL meeting some weeks later (see Event 11), experiences from the two requested school team meetings were discussed. Aud argued that comments in the meetingss had demonstrated the school's *desire* to be part of the projects. The school leader had explicitly said that they wanted to be part of the projects and gain from didacticians' support. Aud also emphasised that she thought the school team meeting served as *reminders* for teachers' engagement in the projects and to "get them started better again":

Ut	Who	What is said (original)
95	Aud	The leader was very clear that they wanted to be in this project since that meant we would support them. He was not aware of the problems they had with equipment and other things. So, I think we have to hope and try sometimes to remind them a little bit that we want things to go on. It was very clear that they were engaged and wanted to do things.

Event 11, Dec 1st 2005, UiA, KUL team meeting, Audio, Episode 1

Eli contributed to the discussion concerning how to *act as didacticians* in developmental projects when little happened in schools. She emphasised that the teachers seemed to *wish to develop* their teaching and *enjoyed* the workshops and their content:

Ut	Who	What is said (original)
120	Eli	…, teachers have volunteered to take part in this or at least the schools have, and I get the impression that most of the teachers all would like to be part of the project and they are enjoying what is going on in the workshops. So it does not seem as if the teachers do not want something to be happening in schools. …

Event 11, Dec 1st 2005, UiA, KUL team meeting, Audio, Episode 2

Thus, to offer more support to assist teachers in developing their teaching both were important for the projects as such and seemed rooted in a desire among the teachers and school leaders to develop teaching. In an end of ICTML interview more than two years later, Aud considered effects of the requested school team meetings and support offered in these meetings. Overall, she argued for increased consciousness among teachers and school leaders and that more started to happen at the schools:

Ut	Who	What is said (translation)	What is said (original)
26	Aud	More started to happen, that is clearly my impression. You had more contact with them, so you know more about this. But it is clearly my impression that they took the meetings seriously and started to consider critically what they could do differently. This included both the school leaders and the teachers.	Det begynte å skje mer, det er mitt klare inntrykk. Du hadde mer kontakt med de selv så du vet mer om dette. Men det er mitt bestemte inntrykk at de tok møtene vi hadde på alvor og begynte å tenke seg nøye om hva som kunnen legges opp annerledes. Det gjaldt både skoleledelsen og det lærerne.

Event 44, Jan 22nd 2008, Aud, End of ICTML project interview, Audio, Episode 3

After considering experiences to draw on for a new project, Aud summarised and concluded that she was happy for the requested school team meetings and increased support of teachers which included Otto:

Ut	Who	What is said (translation)	What is said (original)
52	Aud	Seen today I am happy we did it. Because I believe it would have stopped, we would not have had such a successful project if we had not done this. I think it resulted that more started to happen both at Fjellet and Austpark.	I ettertid så er jeg glad for at vi gjorde det. For jeg tror det hadde stoppet, vi hadde ikke fått så vellykket prosjekt hvis vi ikke hadde gjort det. Jeg tror det gjorde på både Fjellet og Austpark at det kom noe mer i gang.

Event 44, Jan 22nd 2008, Aud, End of ICTML project interview, Audio, Episode 4

In Sections 5.2.3 and 5.2.4, teachers' comments on Otto's support of them are analysed. Besides participation in school team meetings, Otto led a workshop session for all the teachers at Austpark in the computer lab and took responsibility for a number of lessons with spreadsheets at Fjellet. The latter was suggested by *Otto* in the requested school team meeting at Fjellet in October 2005 (see Event 5). He offered the possibility to *be in charge* of the lessons if the teachers preferred so. According to Aud, such a kind of direct support had not been discussed among the didacticians before Otto offered it in the school team meeting at Fjellet:

Ut	Who	What is said (translation)	What is said (original)
24	Aud	I did not perceive it to have been planned from us, but I believe the situation made him thinking that in order to have progress he needed to be more active and simply suggest something. Because I think it was a suggestion which cam up in the meeting we had. …	Jeg oppfattet ikke at det var planlagt fra vår side, men sånn som situasjonen var så tror jeg han fant ut at hvis jeg skal komme videre her så må jeg være litt mer aktiv og rett og slett foreslå noe. For jeg tror det var et forslag som kom opp i det møte vi hadde. …

Event 44, Jan 22nd 2008, Aud, End of ICTML project interview, Audio, Episode 1

In fact, the possibility to get support at the schools through visits from didacticians had been mentioned by Otto *already* in ICTML Workshop 3 in January 2005. In the workshop he phrased the offer as indicated in the episode below, referring to someone "who knows the software" which were related to Cabri being introduced to the teachers in that workshop:

Ut	Who	What is said (translation)	What is said (original)
253	Otto	...to receive follow-ups through visits at the school from someone who knows the software. If that is helpful for you.	...få oppfølging besøk på skolen av noen som kan programmet. Hvis det er nyttig.

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video, Episode 4

Otto, few seconds later, complemented this offer by expressing that his concern was support of *teachers' competence* in using computer software. He received immediate positive feedback from Markus, Ludvig and Trude at Fjellet, while none of the teachers at Austpark responded to the offer during the workshop:

Ut	Who	What is said (translation)	What is said (original)
266	Otto	[I was thinking of the teachers]	[Jeg tenker på lærerne]
267	Otto	for yourselves in order to develop your competence	på dere selv ja for å utvikle kompetansen
268	Markus	Yes and then you are thinking of one who is part of the project that, that could come to us, yes	Ja og så tenker du på også at en være med fra prosjektet her som som kom en tur ja
269	Otto	[yes. Yes exactly]	[ja. Ja det]
270	Trude	[Great]	[Kjempe]
271	Ludvig	[That would be very good]	[Det kunne ha vært veldig ål-reit]

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video, Episode 5

Although the immediate responses from Markus, Ludvig and Trude were very positive, the idea of offering such kinds of support from didacticians was not followed up before the e-mail request in September and the following school team meetings and contributions by Otto commented earlier in this section (5.2.2).

Thus, analytical findings in this section have paid attention to how didacticians during the autumn 2005, the third semester of the participation with teachers, requested school team meetings to give more support of teachers. This was done based on an experienced lack in development in teaching to include computer software use, inquiry and collaboration between teachers which were important aims in the two projects. When considering the increased support in the ICTML project where Otto had an active role, Aud overall concluded that this support had been *successful* and *important* for the development observed.

In Sections 5.2.3 and 5.2.4, I present analytical findings from what I denote as the second phase of didacticians' support of teachers in the implementation phase of Cabri considered in this section. I present and discuss events related to the e-mail request at Fjellet and Austpark, emphasising teachers' reactions to this support. Later, in Section 5.3, activity theory is utilised when analysing didacticians' influences on development in teaching through their support of teachers.

5.2.3 Teachers' comments on support at Austpark

Data from a total of nine events are treated in this section with an emphasis on the two school team meetings requested in the e-mail and letter discussed in the previous section. An overview of these events is presented below in Table 5.2, where the numbered events similar to Table 5.1 refer to the list of events in the case study described more extensively in the overview in Appendix 1.

Table 5.2: List of events considered in this section

Event	Date	Type of sessions
6	26.10.2005	School team meeting at Austpark requested by the ICTML project
8	27.10.2005	E-mail from Harald to didacticians in the ICTML project concerning a scheduled school team meeting and workshop session at Austpark (see Event 12 and 13)
9	04.11.2005	School team meeting at Austpark requested in a letter
12	07.12.2005	School team meeting for Cabri at Austpark
13	14.12.2005	School workshop session at the computer lab at Austpark led by Otto.
16	11.01.2006	LCM Workshop 10 at UiA
30	22.02.2006	LCM Workshop 11 at UiA
31	09.03.2006	End of Cabri-use interview at Austpark
38	05.09.2006	Austpark's KUL conference presentation at UiA

In the school team meetings, all or most of the teachers, a school leader and several didacticians participated as indicated in Appendix 1.The requested school team meeting (see Event 9), based on the letter to Austpark, was as indicated in Table 5.2 held 8 days after the ICTML school team meeting. Since many of the issues brought up in the letter were discussed in the ICTML meeting, I have not included any episodes from the latter meeting since they have not been found relevant to the case analysed in this thesis.

As mentioned, during the ICTML school team meeting on the 26th of October both the vice principal and the teachers made inputs concerning the more overall issues raised in the letter. All of them expressed a *wish for further participation* in both projects which is in accordance with what Aud expressed in the KUL team meeting the day after (see p. 127). In the school team meeting, the teachers at Austpark argued that they were in a *good process* concerning the projects, but because of several reasons they acknowledged that they would have liked to have better progress. However, they also expressed a need for *more precisely expressed expectations* concerning their supposed contributions in the projects. The teachers had joined two projects when their school leader's signed contract for participation, but apparently did not experienced the expressed aims and actions from didacticians to be clarifying for their own actions.

About 20 minutes into the school team meeting, the discussion gradually emphasised implementation of computer software at Austpark. Harald and Gunnar reported from lessons with spreadsheets. Jakob informed everyone that he and Frode *planned to implement Cabri* in their teaching at Grade 8 after Christmas. This statement from Jakob is included in the episode below. To have such a kind of contribution was one of didacticians' aims with the meeting and mentioned by Aud in her introduction at the start of to the meeting. Her repeated yes-comments in the episode indicate a pleasure with what Jakob said:

Ut	Who	What is said (translation)	What is said (original)
316	Jakob	After Christmas, we will work on the topics geometry. And then I will	Etter jul skal vi i gang med emnet geometri. Og da vil jeg
317	Aud	[Yes]	[Ja]
318	Jakob	spend some time to introduce them (*students*) to the tool Cabri	bruke en del tid på å sette de (*elevene*) inn i verktøyet Cabri
319	Aud	[Yes]	[Ja]
320	Harald	Great!	Flott!
321	Jakob	So it will be something new for this Grade 8 class	Så det blir nytt for den åttende klassen
322	Aud	Yes	Ja
323	Jakob	And I think, that Frode too	Og jeg tror det, at Frode også
324	Aud	Yes	Ja
325	Jakob	is interested in starting to	er interessert i å begynne å
326	Aud	Yes	Ja
327	Jakob	use Cabri. But he will need some time to be ready to use Cabri because he	bruke Cabri. Men han trenger også å komme i gang med Cabri for han
328	Aud	[Yes]	[Ja]
329	Jakob	Wants to learn it	ønsker å lære det
330	Harald	Mm	Mm

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio, Episode 1

In her immediate feedback to Jakob in the meeting (see Episode 2 below), Aud emphasised the possibility for Frode, who together with Elise only participated in the LCM project, to join ICTML in order to be supported in use of Cabri. As the project leader of the ICTML project, she very much wanted to observe some development related to the aims of the project such as this example with two teachers' implementation of Cabri. She questioned *why* Frode and Elise did not come to the ICTML workshops, an offer from the didacticians in the ICTML project. In utterance 336, Aud also referred to an *overall aim of the pr*ojects: To *work and learn together*. As evident from the episode below, Harald first tried to address *why* the two teachers *did not* want to participate in the ICTML project but later, in utterance 339, he refused to address the question because of the non-presence of Frode and Elise:

Ut	Who	What is said (translation)	What is said (original)
331	Aud	He (*refers to Frode*) should participate in the ICT workshops in order to have some assistance	Han (*referer til Frode*) bør jo være på IKT workshop'en for å få noe hjelp med det
332	Jakob	Yes	Ja
333	Aud	Yes he, Frode too	Ja han, Frode også
334	Harald	Mm	Mm
335	Harald	But I believe the situation is that Elise and Frode have made a judgement and considered how much they are able to (*interrupted*)	Men det er vel sånn at Elise og Frode har stukket fingeren litt i jorda og vurdert hvor mye klarer de å (*avbrytes*)
336	Aud	[But if he plans to use it in his class why do they not come (*she means participating in the ICTML workshops*) and have some assistance? Why do everything on their own since the point is exactly to learn something together?]	[Men hvis han har tenkt å bruke det i klassen hvorfor kommer de ikke da og er med (*mener her med på ICTML workshopene*)? For da vil de jo få litt hjelp. Hvorfor skal de gjøre alt alene hvis de poenget nettopp er at vi skal lære noe sammen?]
337	Harald	But I believe they feel that they do not have the necessary time to participate these Wednesdays (*refers to the ICTML workshops*). But we cannot (*interrupted*)	Men det er vel kanskje at de føler at de ikke har tid å være med de onsdagene (viser til IKTML verkstedene). Men vi kan ikke (*avbrytes*)
338	Aud	[But it is twice, it is usually twice as much work to do on your own]	[Men det er dobbelt, jo som regel dobbelt så mye arbeid å gjøre det alene, alene]
339	Harald	But we cannot talk about them when they are not here	Men vi kan ikke snakke om de når de ikke er her

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio, Episode 2

This episode illustrates how Aud encouraged and wanted to direct teachers' actions in schools with reference to aims in the projects. This raises issues for responsibility in development in teaching which is discussed in Section 5.3.2.

Less than a minute after the intervention from Aud in Episode 2, Jakob again referred to his and Frode's plans for use of Cabri after Christmas *inviting* the didacticians to come. Then Aud, on behalf of didacticians in the ICTML project referred to the possibility of getting *assistance from Otto* "in planning geometry and Cabri", who she referred to as being "fairly clever at this" (see Episode 3 below). This offer was well received by Harald who articulated *appreciation* of this offer leading the discussion into a phase where the *form of contribution* from Otto was discussed.

Ut	Who	What is said (translation)	What is said (original)
353	Aud	But, then. We have an offer if you wish to have a visit from Otto for example exactly to assist in planning geometry and Cabri. He is fairly clever at this	Men altså. Vi har tilbud hvis dere vil ha Otto på besøk net-topp for eksempel i planlegging av geometri og Cabri. Han er ganske god på det
354	Harald	It could really be valuable if we reserved time once so Otto could have arrived and taken	Det kunne absolutt vært aktuelt at vi satte av en gang der Otto kom og tok
355	Jakob	[Yes]	[Ja]
356	Aud	It may be in the planning together with you or even in the class	Det kan være i planlegging med dere eller for så vidt også i klassen
357	Harald	Yes, concrete advice for starting with Cabri. What is sensible to do first? Yes that would be great	Ja, konkret tips til oppstarten. Hva er lurt å gjøre først? Ja helt klart helt topp å få det
358	Jakob	Yes, starting course for students (*pause*). Well, not a starting course. We could look at a topic	Ja, begynnerkurs for elevene i (*pause*) Vel, ikke begynnerkurs. Vi tar for oss et emne
359	Aud	(*Laughter*)	(*Latter*)
360	Jakob	We have been talking about this before, a course in use of Cabri is not good (*laughter*)	det har vi snakket om før, kurs i Cabri er ikke noe (*latter*)
361	Harald	He he. Problem solving with Cabri (*several laugh*)	He he. Problemløsning med Cabri (*flere ler*)
362	Gunnar	I was thinking quite practical	Jeg tenkte helt konkret
363	Otto	[They have really learnt the discourse (*laughter*)]	[De har lært seg diskursen, hva (*latter*)]

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio, Episode 3

In utterance 358, Jakob emphasised a need for having a "*starting course*" for students in Cabri but adjusted himself soon after followed by much laughter. The teachers had experienced in workshop session led by Otto that he was *critical* to the learning benefits of teaching which emphasised *use of the tool as such*, like ability to use all kinds of formatting options in Excel. As an example, in one of the workshops the teachers were given the following problem to solve in Cabri: "Make a particular signpost which can be enlarged without losing proportions". I consider teachers laughter and Otto's comment to teachers' laughter, arguing that the teachers had "learnt the discourse", to indicate that the teachers were well aware that in accepting his assistance it would have to follow his suggested approach with computer software in teaching.

The day after the school team meeting discussed above, Harald sent an e-mail (see Event 8) to Aud and me informing that two sessions in December had been scheduled. A two hours school team meeting to discuss implementation of Cabri at Austpark, and a two and a half hours workshop session at their computer lab led by Otto (see Table 5.2). To the workshop session (see Event 13) all the teachers at Austpark were invited, not only the teachers participating in the developmental projects. In the e-mail, Harald described the plans for the contributions by Otto in this workshop using the term *start plan* which related to ideas for approaching use of Cabri in teaching at Austpark:

What is said (translation)	**What is said (original)**
On the final Wednesday Otto comes to assist us in making a "start plan" for Cabri.	Den siste onsdagen kommer Otto for å være med å lage et "start opplegg" for Cabri.

Event 8, Oct 27th 2005, Harald, E-mail concerning ICTML, Episode 1

However, the contribution from Otto in the workshop session in December did mainly emphasise *teachers' development* of own *competence* in Cabri (see Appendix 8i, p. 344). Otto is experienced in conducting such sessions and suggested some practical tasks to stimulate the process of developing teachers' experiences in using Cabri and motivating for teaching with Cabri. One month later, during LCM Workshop 10 in January 2006, Frode referred to such a task. Frode had made a figure supposed to look like a bicycle which could be enlarged with the dynamic dragging-function in Cabri.

The possibility to have *Otto coming to Austpark* was later several times emphasised by the teachers as *crucial* for their implementation process of Cabri. In LCM Workshop 10, Jakob referred to Otto's contribution as *brilliant* in the process of stimulating *other mathematics teachers* at Austpark to *dare* start using Cabri:

Ut	**Who**	**What is said (translation)**	**What is said (original)**
191	Jakob	We had a course with [Otto]	Vi hadde jo kurs med [Otto]
192	Ingvald	[Mm]	[Mm]
193	Jakob	who came to us	som var ute hos
194	Ingvald	Mm	Mm
195	Jakob	and accomplished a brilliant course where we had, tried to include as many mathematics teachers as possible	og holdt et glimrende kurs det vi hadde med, prøvde å få med mest mulig matematikklærere.
196	Ingvald	Mm	Mm
197	Jakob	So they could experience the tool being used and potential use of it. I think it was important in order for people to be [able to]	Sånn at de fikk se verktøyet i bruk da hva det kunne brukes til. Det tror jeg var viktig for å få folk til å [kunne]
198	Ingvald	[Mm]	[Mm]
199	Jakob	feel that they dare to start using it.	føle at de tør å begynne med dette her.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 10

In the episode above, Jakob uses the term “course” despite the laugther use of the term “course” had provoked in the earlier quoted episode from the school team meeting. Whether or not Otto’s contribution could be regarded as a workshop session or course and what kinds of difference there might be in didacticians and teachers interpretations of these two terms are not discussed here.

The importance of Otto’s contribution was repeated by Jakob in ICTML Workshop 7 one week later. In an earlier episode in the workshop (see Appendix 8ii, p. 344), he expressed *gratitude* to have been offered the contribution by Otto as part of their participation in the ICTML project. In the end of Cabri-use interview in March 2006, where they considered their teaching with Cabri some weeks earlier, the importance of this offer was once again emphasised by Jakob and Harald (see Appendix 8iii, p. 344). A few seconds later in the same interview, Harald complemented Jakob by emphasising that the contribution from Otto had served as *important for their efforts* to implement Cabri in teaching at Austpark (see Appendix 8iv, p. 345). Later, during the KUL conference in September 2006, Jakob again referred to Otto’s contribution as crucial. Hence, these episodes illustrate how the teachers *appreciated* and *valued* the possibility to have *support by Otto*. Despite indications of problematic progress at Austpark and issues of didacticians controlling development in teaching, teachers’ comments indicate that they experienced a positive outcome. This is discussed further in Section 5.3.

As indicated in the previous paragraphs, some of the episodes in this thesis are attached as endnotes marked chronologically with Roman numeral in Appendix 8. These episodes have been included to give documentation for my claims but are not given extensive treatments in the analysis.

5.2.4 Teachers’ comments on support at Fjellet

I have earlier presented Episode 5 from ICTML Workshop 3 in January 2005 (see p. 129) where Otto presented the possibility that didacticians could support the teachers by visiting them at their schools. In the episode, Markus, Ludvig and Trude responded positively to this offer of support in the ICTML project. However, based on what didacticians experienced as slow progress in implementation of computer software use in mathematics, the e-mail requesting for a school team meeting in the ICTML project was sent (see Event 3). This school team meeting was held almost a month later and another one two weeks after this as indicated in Table 5.2. An overview of the five events considered in this section is presented in Table 5.3:

Table 5.3: List of events at Fjellet considered in this section (5.2.4)

Event	Date	Description
3	28.09.2005	E-mail from didacticians in the ICTML project
5	24.10.2005	School team meeting which included: Trude, Markus, Ludvig, Principal, Aud, Otto and Ingvald
10	07.11.2005	School team meeting which included: Trude, Markus, Ludvig, Otto and Ingvald
	18.11.2005 25.11.2005	Classroom visits in the three teachers classes. Otto is leading the lessons emphasising use of spreadsheet. The lessons are not included as events in the case study
16	11.01.2006	LCM Workshop 10 at UiA
30	22.02.2006	LCM Workshop 11 at UiA

Based on the discussion during the school team meeting on the 24th of October, the second meeting held on the 7th of November was earmarked planning of two times two hours lessons with spreadsheet in each of the three teachers' classes on the 18th and 25th of November 2005. In the first of the meetings, Trude expressed a *lack of experience* with computer software which prevented her from using computer software in teaching. The two other teachers, Ludvig and Markus, also expressed experienced difficulty in leading lessons with computer software use in mathematics teaching referring to experiences with spreadsheet. In response to this, Otto made the suggestion to *be in charge* of the lessons if the teachers preferred so (see p. 129). The teachers at Fjellet *appreciated* the offer from Otto, and the decision was made that Otto would lead teaching lessons as indicated in Table 5.2. During these lessons, the teachers mainly had the role as observer in their own classes and they shared their experiences from observation of the lessons in conversation with didacticians afterwards.

In a group session in LCM Workshop 10, where she was placed together with some of the teachers from Austpark, Otto and Ingvald, Trude expressed gratitude to Otto's initiative. Trude argued that the contribution had served as *crucial* for her implementation and use of Cabri in teaching for the first time 5 days earlier (see Episode 1 below). She expressed a great *personal satisfaction* with being able to implement Cabri in teaching. Trude's comment in utterance 16 indicates concerns for an experienced possible lack of fulfilling *expectations* as part of her participation in the ICTML project:

Ut	Who	What is said (translation)	What is said (original)
9	Trude	We have had visit from Otto and you (*points to Ingvald*) two Fridays and you saw how the situation was. But at least we were able to get things going resulting in that I last Friday started to use Cabri in my Grade eight class!	Vi har hatt besøk av Otto og deg (*peker på Ingvald*) to fredager og dere så åssen vi hadde det. Men vi kom hvert fall i gang og det resulterte i at jeg har begynt nå forrige fredag med Cabri i åttende klassen min!

10	Ingvald	Yes great!	Ja flott!
11	Trude	So, so that is my state of affair	Så så der ligger jeg
12	Ingvald	Mm. Mm.	Mm. Mm.
13	Trude	and I am very satisfied with my-self so far.	og er godt fornøyd med meg selv så langt.
14	Some	Ehe	Ehe
15	Ingvald	Yes great	Ja flott
16	Trude	Since I perhaps not have done what I was supposed to do	Siden jeg ikke har gjort det jeg skulle gjøre kanskje.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 1

One week later, in a plenary session in ICTML Workshop 7, Trude referred to the considered group session above. She once again reported from her use of Cabri emphasising the big *challenge* she had experienced. She referred to the external support by didacticians and her way of *interpreting expectations* from didacticians at UiA using the expression “kick in the back end”:

Ut	Who	What is said (translation)	What is said (original)
172	Trude	During the KUL gathering on Wednesday (*refers to LCM Workshop 10 on week earlier*) we started to talk about Cabri and use of it. I was fairly excited because I had started to use Cabri the previous Friday in my Grade 8 class. I have had visits from Otto and him (*points to Ingvald*)	På KUL samlingen på onsdag (*refererer til LCM Workshop 10 en uke tidligere*) begynte vi å snakke om Cabri og bruk av det. Jeg var nokså høyt oppe fordi jeg fredagen før hadde startet med Cabri i åttendeklassen min. Jeg har hatt besøk av Otto og han (*peker på Ingvald*).
173	Some	[Ingvald]	[Ingvald]
174	Trude	[Ingvald]	[Ingvald]
175	Ingvald	Hi (*waves with a hand*)	Hei (*vinker med en hånd*)
176	Trude	just before Christmas close to the end of November, to sort of have a kick in the “back end” to get started (*refers to teaching with computer software promoted in the ICTML project*). And I know that I am not clever with computer software. So it was big efforts and many new considerations behind it. And I started to read the worksheets from Otto (*refers to a number of Cabri worksheets handed out in ICTML Workshop 3*) and, then I thought, dammit, I just have to do it! And when I am here attending these workshops feeling: No, I cannot do it, but then on Friday I thought I just do it …	like før jul i slutten av november og for liksom å få et spark i bakenden til å komme i gang (*refererer til undervisning med dataprogram vektlagt IKTML prosjektet*). Og jeg er ikke noe flink i data det vet jeg. Så det var et stort løft og mye tanker som lå bak. Og så begynte jeg å lese på det Cabri-heftet til Svein (refererer til et Cabri hefte delt ut på IKTML W3) og, så tenkte jeg filleren heller jeg må jo bare hoppe i det. Så er jeg på disse kursene her og jeg føler liksom at: Nei det her nei, men så tenkte jeg på fredagen nå begynner jeg. ...

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 1

Although Trude had participated in workshops, she still felt unable to implement Cabri in her teaching. She appreciated the visits by the didacticians and Otto's contributions in her class. She argued that this support from the project had served as a "kick in the back end", which finally led her to start using Cabri in her teaching. Hence, the offer of *support* to the teachers in the schools, which was one of the main reason for didacticians' requesting school team meetings, was valued as critical by Trude when reporting from her first ever teaching with Cabri.

5.2.5 Summary

In two workshops during the spring 2005, Cabri was *introduced* for teachers in the ICTML project. In these workshops, didacticians led discussions where *implementation* of Cabri as well as other kinds of computer software in teaching was suggested and the teachers were *challenged* whether they dared to start using it (see p. 124). However, half a year later didacticians' experienced *little use* of computer software and decided to ask for school team meetings to *support* implementation of computer software. These meetings were requested by e-mail to three schools in the ICTML project and by a letter to the principal at Austpark concerning their participation in the two projects.

The intentions with the school team meetings was, from the didacticians' point of view, to *encourage* and *remind* the teachers that didacticians expected development in teaching and hoped to *help* them get *started better again*. Didacticians wanted to *give support* in the developmental process based on a doubt concerning the progress with implementation and use of computer software in mathematics teaching. Findings indicate that Trude experienced the support almost as "a kick in the back end" like she phrased it. The teachers at Austpark also raised questions concerning what kinds of *expectations* didacticians had for teachers' development in teaching.

However, the three teachers which constitute the case later, in different kinds of sessions, argued that the support offered by didacticians were *crucial* for their implementation of Cabri at their school. All three of them in particular referred to the contribution by Otto as important. In Section 5.3 I utilise activity theory to analyse how didacticians influenced teachers' implementation of computer software in teaching.

5.3 Analysis of the didacticians' external support

I have argued that analytical findings in this chapter reveal *tensions* in relation to *three intersecting activity systems* and *issues* teachers addressed in order to have development in teaching with a shared *object* related to implementation of Cabri (see Section 5.1, p. 120). These activity systems were mentioned in Section 5.1 and I particularly relate actions in workshops and school team meetings to the *KUL activity system*. Analytical findings within Section 5.2 call attention to how *external support* from didacticians to teachers in the ICTML project was *experienced* by teachers and *influenced* teachers' implementation of Cabri at two schools. Neither the three teachers which constitute the case nor the other teachers at their schools had ever used Cabri before.

In ICTML Workshop 3, the teachers in the project were introduced to Cabri, worked with Cabri for almost two hours and finally took part in a plenary discussion related to possible implementation of Cabri in teaching. In the KUL activity system, where this occurred as an event, the teachers had the role as being the *subject* and together with didacticians constituted the *community*. In Chapter 3 (see p. 62), objects in my research was formulated in the following way:

> When considering Cabri in my research, the objects are about teachers' implementation, orchestration of Cabri-use in teaching with students' learning of geometry related to requirements in the National Curriculum in Norway.

Since this object initially in teachers' implementation phase with Cabri basically was about the very implementation of Cabri, I will in this chapter mostly simplify and refer to *implementation of Cabri* as the object or main part of the object.

The *workshops*, which included work with tasks and discussions, as well as *school team meetings, classroom- and computer lab visits* in schools all served as *mediating artefacts* for the project. Concerning *division of labour* in the KUL activity system, Goodchild (2008) describes the LCM project pointing to *didacticians* as having a *major role* in planning workshops linked to the *aims* of the *project*. I also argue that the *didacticians* had a *similar* dominating role in at least *two* of the *school team meeting* included in this case study. These meetings (see Event 5 and 6) were arranged based on the e-mail request sent by didacticians to each of the schools in the ICTML project (Event 3) and at Austpark also a *letter* (Event 4). I have used the expressions *requested by the didacticians* to indicate didacticians dominating role in suggesting that the meetings should be held.

According to Goodchild (2008), the National Curriculum, the textbook, the constraints of time and space, didacticians working on research and development in co-learning partnership with teachers were some of the *rules* of the LCM project. I consider these as rules for actions within the KUL activity system, school activity system and teaching activity system. In Section 5.3.2 I emphasise that analytical findings also illuminate a number of *unwritten rules* within the KUL activity system. In later sections unwritten rules within the school- and teaching activity systems are considered as well.

In Section 5.1 I indicated that teachers' work in schools could be analysed with reference to their *teaching activity system* but influenced by the frames set by their *school activity system*. I consider the *teacher* as the *subject* in the teaching activity system. The teachers' main role is to be *responsible* for the teaching of students, and teachers' *actions* are aimed at and designed for the students. Hence, I consider teachers together with students as being the *community* in the teaching activity system. Teachers also operate in *different communities* with different objects in the school which signifies the distinction between school activity system and teaching activity systems.

Thus, when the teachers orchestrate their teaching in classrooms or computer labs, the object, mediating artefact, rules, division of labour and community look quite different from those in the KUL activity system. Teachers' participation in the two developmental projects and didacticians' support provoked *tensions* for the teachers since it introduced a "new" community of people which I analyse as an activity system. In Sections 5.3.1 and 5.3.2, I analyse how didacticians, in an "outside" project like the ICTML project, offered the teachers *support*. The teachers expressed gratitude for the support, but they also in some sessions expressed that the support proposed *expectations* concerning suggested mathematics teaching. For example, during ICTML Workshop 3 and later workshops, didacticians in the ICTML project suggested use of *Cabri* and *ideas* and *tasks* to guide the use of Cabri in teaching. The latter refers to Cabri as a mediating artefact and actions within *teachers' teaching activity systems*.

In Chapter 3, I introduced use of *intersecting activity systems* and Figure 3.6 (see p. 71) as a representation of such systems related to my research study. Figure 5.1 (see p. 185) is such a representation which illustrates how didacticians supported work in the KUL activity system with teachers but also supported and directed actions for teachers' teaching activity systems at Austpark. In Sections 5.3.1 and 5.3.2, the activity theory analysis of didacticians' external support of the teachers illuminates tensions for teachers in the developmental projects. Issues were addressed in order to cope with these tensions and are illustrated with bold text in Figures 5.1 – 5.3.

5.3.1 Teachers' experience of didacticians' support

In Sections 5.2.3 and 5.2.4 I considered teachers' comments to didacticians' support while this section contains an activity theory analysis of how teachers *experienced* the support for their implementation of Cabri. In accordance with Section 5.2 and the two phases of support I have proposed (see p. 122), I first consider the support offered by didacticians in workshops and later in requested school team meetings in the ICTML project where Otto played an important role.

Phase 1: The support offered by didacticians in workshops

Event 1 in the case study was ICTML Workshop 3 where Cabri was introduced to the teachers. In the final plenary at the workshop, two of the teachers explicitly expressed appreciation of one of the *tasks* in the workshop. Harald mentioned a task describing a practical situation and a reason for his appreciation could be the strong requirements for practical applications in L97[21], the National Curriculum in Norway. As argued in Section 3.1, the Norwegian society's requirements for teaching in schools, in the form of a National Curriculum, provide the motives influencing the development of objects for teaching. Thus, this *task* was playing the role as a *mediating artefact* which Harald could connect to *motives* in the Curriculum. This example indicates that the teachers *liked* the *support* in the form of *tasks* since the tasks could be *utilised* in their own teaching activity system particularly through its links to motives in the Curriculum. Teachers' experience of tasks, particularly to go beyond textbook tasks, is mentioned as a potential issue for teachers (see reference to Laborde in Section 2.2.4, p. 39). However, based on Harald's comment, this task did not seem to provoke any tensions within his teaching activity system at Austpark.

After the introduction and work with Cabri in ICTML Workshop 3, didacticians *asked* the teachers whether they felt *ready to use Cabri* in their teaching. The tasks potentially served as a *mediating artefact* linked to the *object* of their teaching activity system, the *upper* level in Leont'ev's model considered in Section 3.1.2 (see p. 61). However, the question of teachers' *readiness* for use of Cabri relates more to the *two* other levels: actions ↔ goals; operations ↔ conditions. The question presupposed that the teachers had decided to *prioritise* use of Cabri. Such a priority is related to teachers' *goals* for *actions* in their teaching which I consider later in this chapter and in Chapter 6. Didacticians gave support by conducting a workshop where Cabri was introduced and teachers worked with Cabri and suggested tasks. By being asked of *readiness* for teaching, quite explicitly, both in workshops and school team meetings in autumn 2005, Trude seemed to have interpreted this as an *expectation* to *implement* and make *priority* of Cabri in her teaching while the teachers at Austpark questioned what didacticians expected them to do. This indicates that the teachers to some extent considered didacticians as being in control of the ICTML project.

The kind of expectations indicated above had by will not been explicitly formulated in an agreement although teachers' school leaders had signed contract for participation in the projects. This would have been impossible to do and against the nature of the developmental research

[21] The abbreviation L97 was introduced in Table 2.1 on page 28

projects. Trude expressed an interpretation of the expectation when she in a workshop session responded by arguing that she had to *reserve time* indicating a necessity of priority on use of Cabri (see Section 5.2.1, p. 124). In a later workshop she also commented her *lack* of doing what she was *supposed to* do (see Section 5.2.4, p. 138). Trude interpreted her participation and didacticians' support in the developmental project to set demands for her actions: Here to use Cabri as a mediating artefact in teaching potentially with tasks offered by the didacticians. Also the teachers at Austpark referred to time and the need of *reserving time* when they considered use of Cabri (see Section 5.2.3, p. 134). Time as an issue will be emphasised later in Sections 5.4 and 5.5.

Phase 2: Support offered by didacticians at teachers' schools

The initiative from didacticians when requesting school team meetings in autumn 2005 was a new stage in their desire to *influence* the *object* and *mediating artefacts* within the school- and teaching activity system. This support from didacticians provoked a *tension* to the *division of labour*. Who were supposed to control and make decisions for what to emphasise in teaching? The example with Trude illustrates that she experienced expectations from didacticians as part of participating in the project. The discussion in the school team meeting at Austpark on the 26th of October indicate that the teachers expected more *explicit expectations* from didacticians in the projects. This issue raises another tension since an *expected outcome* of the ICTML project was to stimulate that teachers together developed their *own goals for teaching with computer software.*

Otto's contributions at Fjellet and Austpark were highly *appreciated* by Frode, Jakob and Trude. In workshops in January and February 2006 (see Event 16 and 30), Trude referred to her *lack* of *skills* in using computer software and lack of *experience* in implementing software in teaching. Further, how she considered Otto's contributions at Fjellet in November 2005 as *crucial* in stimulating her to *dare* implementing Cabri for the first time early in January 2006. Assisted by Otto she overcame this *tension* and had an *expansive development* for her teaching activity system regarding use of the computer software tool Cabri.

Jakob and Frode both referred to Otto's contribution at Austpark on the 14th of December 2005, where according to Jakob he held a brilliant course in use of Cabri for all the teachers at the school. In Section 5.4, findings reveal that Jakob and Frode emphasised *inclusion* of the *whole community* of mathematics teachers to implement Cabri as a *desired outcome* for the school activity system at Austpark based on a rule of similar teaching at Austpark (illustrated in Figure 5.2, p. 186). In the e-mail from Harald (see Event 8), the contribution by Otto was described with an aim to "assist us in making a start plan for Cabri". Consequently, Otto's contribution was supposed to assist their implementation of Cabri at Austpark by supporting teachers' *actions* and *operations* in teaching. The teachers several times afterwards pointed to this contribution by Otto as crucial for their implementation of Cabri in teaching. This repeated emphasis serves as *evidence* that the support from the project was *crucial* for the teaching of Cabri at Austpark.

Why did the teachers at Austpark emphasise Otto's contribution at Austpark as crucial? One reason could be that Otto's contribution served as an important basis for the *third* level in Leont'ev classification: operations ↔ conditions. They experienced Otto's contribution as help for carrying out teaching within the conditions at Austpark. A number of the teachers had already *approved* the suggested *object* and *priority* on implementation of Cabri and interpreted use of Cabri to serve as a motive in the Curriculum (*upper* level). To have Otto at the school and to invite colleagues at the school, who not were parts of the development project, helped to stimulate an *expansive development* at *Grade 8* since teachers' earlier lack of competences in Cabri had prevented development. The expansive development resulted from a process of implementing Cabri in the school activity system as well as in three teachers' teaching activity systems at Grade 8 in Austpark.

5.3.2 Didacticians' support experienced as pressure

So far I have referred to findings illustrating that didacticians in the KUL activity system offered support but also *implicit expectations* for teaching in schools. The ICTML project emphasised use of computer software in mathematics teaching. Priority on use of computer software, in this case Cabri, became consequently a *rule* for the activity in the KUL activity system and didacticians seemed to have expected that this priority-rule was adopted in each teacher's teaching activity system. Didacticians in the KUL activity system arranged workshops emphasising use of Cabri, and also requested school team meetings that *strengthened expectations* of the teachers.

Episode 2 from a school team meeting in October at Austpark (see Section 5.2.3, p. 133), illustrates how didacticians in the KUL activity system also expected the teachers to *receive* and *use the support* they were offered in the project. Aud questioned why Frode and Elise, who only participated in the LCM project, did not attend the ICTML workshops to receive the support and engage in use of Cabri. In utterance 338 Aud argued that it is usually twice as much work when you work on your own, and in utterance 336 she referred to one of the aims of the projects: "…the point is exactly to learn together". The didactician referred to an *aim of the project* which served as a *rule* in the KUL activity system but which was not necessarily shared by the teachers within their teaching activity system. Thus, didacticians seemed to have wanted to influence actions. From analytical findings in this chapter, it is evident that the teachers at Austpark needed to consider their colleagues and rules within their school activity system in order to have the suggested development with implementation of Cabri in their teaching activity system. Hence, didacticians' support provoked a tension within the KUL activity system and for each teacher's teaching activity system and challenged their rule of similar teaching within their school activity system.

I interpret Otto's special support at Fjellet, where he accomplishes lessons with spreadsheets in teachers' classes, as a *mediating artefact* to propose actions in schools. This kind of explicit support served as an *internal tension* for the KUL activity system since it had not been discussed among the didacticians before it was suggested by Otto in a school team meeting at Fjellet. Thus, such kind of support had not been suggested as a rule for work in the KUL activity system, and it could raise tensions concerning *ownership* for the *goals* of *actions* in teaching. A teacher could interpret the intervention by Otto as didacticians showing the teachers how they were *supposed to teach*, consequently offering at *tension* for the *division of labour* in the school- and teaching activity system and the *outcome* for the KUL activity system. The proposed division of labour in the KUL activity system was indeed based on an acknowledgement that the teachers were responsible for teaching in school. As emphasised in Section 5.3.1, analytical findings indicate that *Trude appreciated the support from Otto* which helped her in the implementation of Cabri. Hence, a *contradiction* was generated energising an *expansive development* concerning her implementation of Cabri within her teaching activity system at Fjellet. Trude's response in one of the workshops in January 2006, where she reported that the contributions from didacticians served as "a kick in the back end" (see Section 5.2.4, p. 138), indicates that the contributions from Otto and other didacticians served as *pressure* for her development. Her expressed pleasure and satisfaction in sessions where she considered her efforts with Cabri could indicate a *release* of this *pressure*. This pressure could be related both to her participation in the ICTML *project,* and her wish of improving competence in teaching with computer software offered as statements in the National Curriculum.

A third example of how the teachers were expected to *receive* and *use the support* they were offered was when the teachers at Austpark, in a school team meeting, discussed the *form* of the contribution from Otto. Jakob expressed a need for applying a kind of starting course in Cabri for students but quickly corrected himself because he and his colleagues knew from experience that Otto was critical with respect to the pedagogical value of courses in use of computer software. They knew Otto's assistance would be in according with his *rules*: To work investigatively and collaboratively with Cabri and other kinds of computer software in mathematics teaching. Examples in this section illustrate an *unwritten rule* linked to the aim of the project: *When the didacticians offered support it also presupposed expectations and a pressure on teachers to receive and utilise the offered support*. Hence, teachers experienced expectations related to *support* by didacticians in the projects. Analytical findings in Section 5.2.3 illustrates that Aud responded very positively when Jakob reported his and Frode's plan for implementation of Cabri while later findings in Chapter 6 illustrates how Aud questioned why the same two teacher did not think inquiry would be appropriate in teaching with Cabri at Grade 8. This indicates that Aud as a didactician wanted to observe coherence between emphasise in support and observed teaching.

5.3.3 Summary and further considerations

To summarise, near the end of ICTML Workshop 3 Aud asked the teachers whether they felt *ready* to apply Cabri in their teaching. This question related mostly to the *third* level of Leont'ev: Were the teachers ready to *orchestrate* use of Cabri in their teaching in the form of *operations* within *conditions* at their schools? The question presupposed that the teachers shared *didacticians' object* concerning priority on Cabri and were ready to go through an implementation process with Cabri at their schools. During school team meetings at the schools, Jakob and Frode's comments indicate that this presupposed object *was shared* or at least found valuable by them and they implemented Cabri in their teaching in January 2006. In LCM Workshop 10 in January 2006, Trude reported that she too five days before the workshop had started to use Cabri in her class.

The relationship between the *external* suggested object offered by didacticians in the KUL activity system and *internal* elements constituting teachers' objects for implementation, orchestration of Cabri-use and students' learning of geometry and goals for teaching with Cabri will be considered in the coming sections. To which extents were teachers' objects for their teaching their own objects and not only an object offered by the project? How can I illuminate teachers' objects for teaching with Cabri, in particular how do the teachers motivate their objects? This will be discussed in the coming sections when focusing in the analysis on teachers' *motives* and *goals* for implementation of Cabri within their activity systems. Teachers' goals for implementation and use of Cabri are considered further in Chapter 6 in analysis of teachers' comments on their teaching and what they emphasised in their teaching. In Chapter 7 I present conclusions and implications from analysis of Frode, Jakob and Trude's implementation of Cabri. There the relationships between the observed teaching and the *suggested way* of working with Cabri are considered. The suggested way refers to suggestions for computer software teaching by didacticians in the ICTML project and requirements by policy makers through the Curriculum.

5.4 Jakob and Frode's implementation of Cabri

I consider the school team meeting requested by didacticians in the ICTML project (see Event 11) as the starting point for my analysis of Jakob and Frode's *motives* and *goals* for implementing Cabri (see Section 5.5). In this meeting, Jakob briefly introduced didacticians to his and Frode's plans for use of *Cabri* in their classes at Grade 8 (see Section 5.2.3, p. 132). An outcome from this meeting was a decision concerning arrangement of another school team meeting at Austpark on the 7th of December to plan their later use of Cabri. Thus, in these two meetings, the teachers considered *implementation* of Cabri.

In Section 5.4.1, I present *reasons* why Jakob and Frode wanted to implement Cabri in their mathematics teaching at Grade 8 and why the teachers at Austpark wanted to participate in the developmental projects. Findings in Section 5.4.1 are based on teachers' comments in meetings, interviews and workshops. Section 5.4.2 emphasises *issues* expressed by the teachers in their implementation process with Cabri and their efforts to address these issues. Later, in Section 5.5, teachers' commitment to address and overcome these issues is analysed further utilising activity theory. Lack of addressing issues potentially obstructed development of collective objects in their school activity system and teaching activity systems. However, in some cases teachers' efforts to overcome these issues energised *contradiction* and *expansive development* (see Section 5.3.2, p. 143) in both their school activity system and for their teaching activity systems.

In Sections 5.4.1 and 5.4.2, data from a total of eight events are considered. An overview of these events is presented below in Table 5.4 similar as in Table 5.1 (see p. 127).

Table 5.4: List of events considered in Sections 5.4.1 and 5.4.2

Event	Date	Type of sessions
2	20.04.2005	ICTML Workshop 4 at UiA
6	26.10.2005	School team meeting at Austpark
12	07.12.2005	School team meeting for Cabri at Austpark
16	11.01.2006	LCM Workshop 10 at UiA
31	09.03.2006	End of Cabri-use interview at Austpark
35	29.03.2006	LCM/ICTML interview at Austpark
38	05.09.2006	Austpark's KUL conference presentation at UiA
39	29.11.2006	ICTML Workshop 10 at UiA

5.4.1 Reasons for the implementation of Cabri at Austpark

Why did the teachers at Austpark implement Cabri? This question was explicitly raised by me in the end of Cabri-use interview at Austpark (see

Event 31) and the teachers in the interview and also by their comments in other sessions considered reasons for their implementation. The end of Cabri-use interview was conducted a bit more than a month after their teaching with Cabri ended that year and included Jakob, Frode and Harald and myself as the interviewer.

During the interview, I argue that the teachers listed *four* main reasons for their implementation of Cabri. In the episode below, three of the reasons are considered. *First*, the fact that a *school licence* for Cabri had been bought by the school half a year earlier and installed at Austpark's computer lab some months earlier. *Second* the influence from being part of the *ICTML project* where use of Cabri was discussed and emphasised. The *third* reason was set out by Frode when he argued that they really wanted to do something "new" in their mathematics to "increases students' motivation for mathematics" (see utterance 52):

Ut	Who	What is said (translation)	What is said (original)
39	Jakob	Gunnar had already bought a school licence for Cabri before I came to the school	Gunnar hadde kjøpt inn Cabri når jeg begynte her
40	Some	Mm.	Mm.
41	Jakob	but the software was not yet installed on the machines. So so you (*refers to the other teachers*) had already started with preparations to	men det var bare at det var ikke installert på maskinene. Så så dere (*refererer til de andre lærerne*) hadde jo allerede begynt å jobbe med forberedelser til
42	Harald	Certainly we had some experience from attending courses and tried a bit	Vi hadde jo vært litt på kurs og prøvd litt ja
43	Jakob	[Mm]	[Mm]
44	Ingvald	[Yes]	[Ja]
45	Harald	Mm.	Mm.
46	Harald	No	Nei
47	Jakob	I think it was during the autumn and the KUL seminars (*probably referring to ICTML workshops*) and that we actually had Cabri	Det var vel i løpet av høsten og på KUL seminarene (*refererer trolig til ICTML workshopene*) også da at vi hadde noe Cabri
48	Frode	[Mm]	[Mm]
49	Jakob	and we really wished to try to use Cabri in geometry	og vi ville vi gjerne prøve å bruke Cabri i geometri.
50	Harald	Mm.	Mm.
51	Jakob	Was it not like so?	Var det ikke det?
52	Frode	Yes and we had a desire to do something new in mathematics teaching well constantly it is said that the state of affairs in mathematics is so bad now compared to before. And all the problems that gives. So then to try	Jo det og så var det et et ønske om og så gjøre noe nytt i matematikkundervisningen en hører jo stadig at det er jo mer som er dårligere nå i matematikk enn det det var før. Og alle problemene med det. Så det og så prø-

		out something which in the first place may increases students' motivation for mathematics; but there I feel there are a couple of things that need to be done. If you ask the students who come to us from the primary school, mathematics is not the subject they say they like. They usually do not like it. And then you think, I really wanted to try something, something new simply for the sake of motivation.	ve ut ting som kan gjøre for det første at elevene blir motivert for matematikk; men der føler jeg det er en del som må gjøres. Elevene kommer fra barneskolen og så er de så hvis du spør hvilke fag de liker så er ikke det matematikk altså. Det liker de ikke som regel. Og så kan en, jeg hadde veldig lyst til å prøve noe noe nytt altså rett og slett for motivasjonens skyld også.
53	Ingvald	Mm.	Mm.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 1

The teachers' desire to try out something new was also addressed by Frode ahead of their Cabri-teaching. In the school team at Austpark, on the 7th of December, he asked *whether* the teachers at Austpark wanted to use what he denoted as a modern tool such as Cabri instead of the traditional compasses in geometry. He started it off referring to input from Otto at a national teachers conference in mathematics held in Trondheim, some weeks earlier and in this episode Jakob gave brief supportive feedbacks "Yes" and "Mm":

Ut	Who	What is said (translation)	What is said (original)
29	Frode	I have to say that the debate well, was it a debate?, in Trondheim concerning use of Cabri versus use of compasses and	Jeg synes jo den der debatten vel, var det en debatt?, i Trondheim om bruk av Cabri kontra, i forhold til bruk av passer og
30	Jakob	[Mm]	[Mm]
31	Frode	ruler is very exciting. And I must admit I woke up when Otto questioned why we use yesterdays	linjal er kjempespennede. Og jeg får jo en litt vekker når Otto sier det at hvorfor bruke gårsdagens
32	Jakob	[Yes]	[Ja]
33	Frode	tools when we have today's and the next days	redskaper når vi har dagens og morgensdagens
34	Jakob	[Mm]	[Mm]
35	Frode	straight in front of us. So what I consider is whether we on our school ought to say anything about this? May we replace compasses and ruler by Cabri? Or use them in combination?	rett foran oss. Så jeg lurer litt på om vi på vår skole om vi skal si noe om det? Om (…). Skal vi legge vekk passer og linjal og kun kjøre Cabri? Eller kjøre en kombinasjon?
36	Jakob	[Mm]	[Mm]

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 2

A *fourth* reason for teachers' implementation of Cabri was expressed by Harald in the continuation of the end of Cabri-use interview. Harald mentioned *Jakob's* entry into the school team as crucial:

Ut	Who	What is said (translation)	What is said (original)
54	Harald	And then the fact that you (*refers to Jakob*) were more confident in it than us. Well, you knew it better than us. And you were also ready to start implementing it after, after Christmas. I think we need to have it like that, I try it after Christmas?	Og så den biten med at du (*refererer til Jakob*) var litt tryggere på det enn oss. Altså, du hadde litt mer kjenneskap til det enn oss. Og var litt klar på å begynne etter etter jul. Vi trenger litt sånn at, jeg prøver etter jul ikke sant?
55	Harald	[and then we just follow on and we made a decision]	[og så hiver vi oss på og så bestemte vi oss]
56	Frode	[Mm. Mm.]	[Mm. Mm.]

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 2

Jakob knew Cabri from his experience as master student at UiA where he had been in contact with another master student who had experience with Cabri in teaching, Henning Bueie. Jakob described Henning Bueie as quite experienced in working with Cabri, and Bueie[22] had designed a teaching package which could be used as an aid when teaching with Cabri. It is evident from analytical findings in Chapter 6 that the teachers did decide to use this *teaching package* in most of their Cabri lessons. The nature of the teaching package is considered in Chapter 6.

In utterance 54 in the episode above, Harald substantiated the importance of Jakob's readiness to use Cabri for the team of teachers at Austpark. He emphasised that when one teacher started to implement Cabri, others more easily could "follow on". Less than a minute later Harald suggested an implication of such *collaboration*. He mentioned that several teachers wished to start using Cabri, and by having an initiative from Jakob he pushed them all forward:

Ut	Who	What is said (translation)	What is said (original)
62	Harald	…It was not only one who had to do it on his own but we were several who wished to try. But it was an initiative	…Det var ikke en som måtte gjøre det alene men vi var flere som hadde lyst til å prøve. Men det var et initiativ
63	Jakob	Yes	Ja

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 3

What Harald pays attention to is an advantage of working together as a team at the school. Later in the interview, the teachers paid attention to the importance of *Otto's* contributions at Austpark supplementing what I considered as their second reason for implementing Cabri: The influence from being part of the ICTML project. Thus, it is evident from this inter-

[22] In the rest of the thesis I only use Henning Bueie's family name Bueie when I refer to him as the author of the teaching package.

view, which took part after their implementation and orchestration of Cabri-use in teaching, that the teachers considered didacticians' support to have contributed in their implementation of Cabri.

Now I pay attention to comments and discussions were the teachers considered more in general *why* they wanted to *participate* in the LCM and ICTML projects. In the LCM/ICTML focus group interview at Austpark in March 2006 (see Event 35), the five teachers in the projects were asked to give comments as to *why* they wanted to participate in the projects. In this interview, Austpark's vice principal, Eli, Aud and Ingvald were present in addition to the five teachers. In utterance 35, Frode first pointed to a desire for doing something *new* in mathematics teaching based on his experience of a *low motivation* for mathematics among students. This is the same argument he expressed in the end of Cabri-use interview twenty days earlier (see Episode 1, p. 148). In the focus group interview, he continued arguing why he wanted to take part in a *learning community*. He had a wish to improve his teaching to be more exciting (see Episode 1 below). It is not clear from Frode's utterance in this episode or any other utterances by Frode in the interview what kind of a learning community he referred to, but in Harald and Gunnar's responses to Frode's comment they added to his comment. They argued that the establishment of a *mathematical group* of *teachers* at Austpark, *just before* the start of the LCM and ICTML project, was important for their *readiness* to participate in the projects:

Ut	Who	What is said (translation)	What is said (original)
35	Frode	I am participating because I want to do something with the mathematics teaching, I notice that the students when they arrive from primary school are not motivated for mathematics. They think mathematics is boring; I think it is the typical situation in all the classes, so I really had a desire to take part in such a learning community to get good ideas and assistance to be able to develop more exciting teaching.	Jeg er jo med for at jeg har lyst til og så gjøre noe med matteundervisningen, jeg ser at elevene når de kommer fra barneskolen, ikke er motivert for matematikk: De synes at matte er kjedelig, det er gjengs i alle klasser føler jeg, så jeg hadde lyst til å være med i et sånn læringsfellesskap for å få gode ideer og hjelp til å, å drive spennende undervisning.
36	Harald	I think that we just had started the mathematics group, is not that correct? After the EMIL conference (*refers to a conference held in the beginning of 2004 after a mathematics educational project for teachers*).	Altså vi hadde vel akkurat startet den mattegruppa, hadde vi ikke det? Etter EMIL-konferansen (*refererer til en konferansetidlig i 2004 etter et etterutdanningsprosjekt i matematikk for lærere*).
37	Gunnar	I think it was a result of being in a phase where (*interrupted*)	Det var vel en konsekvens av at vi var i en fase der (*avbrytt*)

38	Harald	We decided we wanted a group where we could sit together and talk. So it was perfect to have the input from you (*refers to the LCM and ICTML projects*).	Vi fant ut at vi ønsket en sånn gruppe der vi kunne sitte og prate litt. Så det var perfekt å få det innspillet herifra (*refererer til LCM og ICTML prosjektet*).

Event 35, Mar 29th 2006, Austpark, LCM/ICTML interview, Audio, Episode 1

In the following discussion in the interview, Elise referred with some uncertainty to the role of the vice principal in the establishment of the mathematics group of teachers at Austpark ahead of the projects and why she wanted to participate in the projects (see Episode 2 below). In utterance 42, Elise added to Frode's comments in utterance 35 emphasising her desire to be a *better* mathematics teacher, teaching mathematics in a more exciting way and generally comments on her pleasure of attending courses in mathematics. Similar to the interview 20 days earlier, Jakob's entrance in the school team was considered and Jakob referred to the role of the principal and his colleagues when he was included in the team:

Ut	Who	What is said (translation)	What is said (original)
40	Elise	Yes, I am thinking why we initially wanted to take part; I think it came from our Vice Principal?	Ja, jeg tenker på hvordan vi ble med; jeg tror det kom fra Vice Principal?
41	Gunnar	Yes, I wonder if it was the Vice Principal?	Ja, jeg lurer på om det var Vice Principal som gjorde det?
42	Elise	I said yes because I am a little like Frode, I wish that I could make the teaching a bit more exciting, and because I knew this it gave the possibility to be perhaps a better mathematics teacher. So I was mainly considering my own situation, to possibly develop my own teaching. I am always ready for courses.	Jeg sa ja fordi jeg er sånn som Frode, jeg skulle gjerne ønske at man kunne gjøre undervisningen litt mer spenstig, og fordi at jeg visste det gav meg muligheter til å bli en kanskje bedre mattelærer. Så jeg tenkte først og fremst for min egen del, å kanskje forbedre min undervisning. Jeg er alltid giret for kurs.
43	Ingvald	Yes, mm, yes but then	Ja, mm, ja, men da.
44	Gunnar	And then Jakob came	Og så kom Jakob.
45	Jakob	Yes, I started on the this school in autumn last year, and I think it was really, yes I wonder if it was the principal who told me this, that I perhaps should be included in this group. Then he also wondered if I would like to be part of these KUL. Or perhaps it was one of you who asked me about participation in KUL. I think it was the principal who asked me about participation.	Ja jeg begynte jo på skolen her i fjor høst, og da var det vel egentlig, ja, jeg lurer på om det var rektor som sa det til meg da, om at jeg kanskje burde være med i denne mattegruppa. Da lurte han på om jeg også ville være med på det, disse her KU. Eller kanskje det var noen av dere som spurte om jeg ville være med i KUL. Jeg tror rektor spurte om jeg ville være med.

Event 35, Mar 29th 2006, Austpark, LCM/ICTML interview, Audio, Episode 2

Although Jakob started his participation in the projects one year after the other teachers at Austpark, he had observed a number of workshops as master student at UiA (see Section 4.5.2, p. 102) so he had some experience of the projects.

I consider the process with Austpark's participation as an interesting story where *Gunnar*, at least seen from the didacticians' point of view, seemed to have been *crucial* in the initial phase when they wanted to sign in for participation in the projects. The planning phase of the projects included making contact with schools and inviting some schools with leaders and a number of mathematics teachers to an information meeting in the spring 2004. Austpark was not one of the schools who were selected to be invited into this process, but Gunnar attended an open seminar at UiA in the spring 2004 where Eli introduced the audience to the LCM project. After the seminar Gunnar talked with Eli and asked expliclty if Austpark could take part. He also, on behalf of the school, showed great interest for the LCM project in an e-mail where he sketched concerns for work in the school team at Austpark. These responses from Gunnar led to a formal contact between didacticians at UiA and leaders at Austpark. Shortly afterwards the contracts for participations in both projects were signed by a school leader at Austpark.

To summarise, a group of mathematics teachers at Austpark was already established before the school's signing of contracts in the projects. Both the principal and vice principal seemed to have stimulated teachers' desire to establish this group and participation in the projects as well as the personal interest and initiative from Gunnar. Jakob also pointed to how the principal and colleagues stimulated him to enter the projects when he started his teaching career at Austpark in August 2005. The teachers wanted to be in a group where they could share their experience in the process of improving their mathematics teaching and discuss students' learning. Thus, I consider what I have argued in the latest paragraphs to contribute as a *fifth* more general reason for their efforts to *collaboratively* implement Cabri.

Finally, I suggest yet another reason for Jakob and Frode's implementation efforts for Cabri although I later consider it as one of their arrangement in their orchestration of Cabri-use (see Section 6.1.2). During the winter 2006, Jakob, Frode and Eivind, the third mathematics teachers at Grade 8, used Cabri alongside use of compasses. During their conference presentation seven months after their Cabri teaching came to an end, Frode summarised their use of *Cabri* and *compasses* as two kinds of tools which they had wanted to take *advantage* of using almost in *parallel* in their teaching. Thus, I consider that the teachers saw possible advantages with use of two construction tools as a *sixth* reason for implementing Cabri.

Ut	Who	What is said (translation)	What is said (original)
79	Frode	But we chose to teach quite in parallel, we worked with exactly the same both in classrooms (*it seems like he means the computer lab and use of Cabri*), and on the blackboard with compasses. So we really wanted it to look similar on Cabri and on the blackboard	Men det har vi valgt å kjøre sånn parallelt løp da, der vi jobber med akkurat med det samme i klasserommet (*her virker det som han mener datalab og bruk av Cabri*), og på tavla med passer og linjal. Så det var egentlig, tanken var at det skulle se likt ut i Cabri som på tavla.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 7

In this episode, Frode referred to teaching with compasses on the blackboard, and when he talked about the classroom it seems to be about the teaching with Cabri on the computer lab.

In this section (5.4.1), six reasons for the teachers' efforts to implement Cabri in mathematics teaching at Austpark have been illuminated:

1. A school software licence for Cabri had been bought and installed on the computers.
2. The influence from being part of the two projects, in particular the ICTML project and Otto for their implementation of Cabri.
3. A desire to do something "new" in mathematics teaching.
4. The inclusion of Jakob in the school team.
5. A desire more in general to collaborate in a group with mathematics teachers at the school.
6. Take advantages of using both Cabri and compasses in geometry teaching.

5.4.2 Issues considered when implementing Cabri

Based on analytical findings in the previous section I listed six main reasons for teachers' implementation of Cabri. In this section I emphasise *issues* met and addressed by the teachers in their implementation process, and their struggles to overcome some of these while other issues were not overcome. The following five main issues are considered in this section:

a) Collaborative work and implementation of Cabri at Austpark.
b) Students' lack of free access to Cabri at home.
c) Access-priority to computer labs at Austpark.
d) Time on the geometry topic.
e) Lack of testing outcome of Cabri teaching.

a) Collaborative work and implementation of Cabri at Austpark

Resistance to use of Cabri among the *colleagues* at Austpark was emphasised by Gunnar in ICTML Workshop 4 in April 2005. I interpret

Gunnar and Harald's concern for Cabri in this workshop to indicate that they both considered implementation of Cabri and how to stimulate the other mathematics teachers at the school to do the same. In the workshop, Gunnar argued for a *lack* of a *direct requirement* in the *curriculum* concerning use of DGS in mathematics teaching (see Episode 1 below). He particularly expressed how this lack of requirement in the Curriculum made it hard to engage his colleagues to implement Cabri in their teaching:

Ut	Who	What is said (translation)	What is said (original)
19	Gunnar	…we have had discussion among colleagues at Austpark. Some mean that it is totally unnecessary with Cabri. They ask	…sånn diskusjon vi har hatt i litt i kollegiet på Austpark skole. Noen mener det at det er jo helt unødvendig med Cabri. De spør
20	Otto	[Yes]	[Ja]
21	Gunnar	why bother to use it? [Therefore]	hva skal vi med det? [Altså]
22	Otto	[Yes]	[Ja]
23	Gunnar	It is not phrased in the curriculum (…) to use Cabri, it says that we are supposed to construct a bit.	Det står jo ikke i læreplanen (…) bruke Cabri, det står at vi skal konstruere litt og så sånn.
24	Otto	It is different tools	Det er forskjellige verktøy
25	Gunnar	Yes, and then we stress the point about different strategies. But where is it phrased? (*Laughter*). So we have some discussions.	Ja og så sier vi det med ulike strategier. Hvor står det hen da? (*Latter*). Så det er litt diskusjoner.

Event 2, Apr 20th 2005, UiA, ICTML Workshop 4, Video, Episode 1

The contribution from Gunnar was followed up by Aud who referred to *general requirements about ICT use* in the mathematics part of the curriculum (see Episode 2 below). However, the issue raised by Gunnar was not really addressed. His comments to Aud's utterances seem to indicate that Gunnar himself was well aware of these requirements in the Curriculum. His problem seemed to be to convince his colleagues about the pedagogical benefits of Cabri:

Ut	Who	What is said (translation)	What is said (original)
26	Aud	The old Curriculum says quite a lot about (*referring to the National Curriculum, L97*)	Det står faktisk ganske mye i den gamle planen om (*refererer til læreplanverket L97*)
27	Gunnar	[Yes. Yes. Yes]	[Ja. Ja. Ja]
28	Aud	integrating ICT if you are able to read the general part of the	å integrere IKT hvis du greier å lese den generelle delen av
29	Gunnar	[Yes that is true. Yes]	[Det gjør det ja. Ja]
30	Aud	mathematics part in connection	matematikkdelen i sammenheng
31	Gunnar	[Yes]	[Ja]
32	Aud	It says quite a lot.	Det står det en hel del der.

Event 2, Apr 20th 2005, UiA, ICTML Workshop 4, Video, Episode 2

More than half a year after this workshop, none of the teachers at Austpark had implemented Cabri in teaching. Implementing Cabri was raised again by Harald about 8 minutes into the school team meeting at Austpark on the 7th of December 2005 (see Episode 5 below). Harald questioned in what ways Cabri could be implemented in their teaching, offering the idea of using Cabri in *similar ways* at all three grades (eighth to tenth grade). It is not clear from the episode whether Harald' utterance referred to all the mathematics teachers or just the five teachers in the projects at Austpark, but I interpreted his contribution to refer just to the five teachers in the projects. Frode responded to Harald's statement by questioning whether it would be possible to use Cabri in a similar way at all three grades. Instead he suggested a kind of *common introduction* to which several of the teachers respond positively:

Ut	Who	What is said (translation)	What is said (original)
71	Harald	Maybe we could try to do something jointly, study how we carry it out and then evaluate it afterwards, like we have done before?	Skal vi prøve på å gjøre noe felles, og se hvordan vi gjør det og så evaluere det etterpå, sånn vi har gjort før?
72	Frode	[If it is possible to do it in a similar way both at Grade 8 and 10?]	[Hvis det kan gjøres likt på 8. og 10. trinn?]
73	Harald	Well, that is the question?	Nei, det var det?
74	Frode	Perhaps it will be a kind of introduction for everyone anyway?	Det bli kanskje en form for innføring for alle uansett?
75	Elise	[Cabri, yes it will be]	[Cabri, blir jo det]
76	Several	Yes	Ja

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 5

From utterance 77, the discussion continued with a focus on students' background in geometry when entering the lower secondary school (Grade 8). Furthermore, how *students' minimal experiences* with making geometrical constructions would influence the possibility to use Cabri at Grade 8. About 5 minutes later, Harald brought the discussion back to his earlier emphasis on how to implement Cabri as a group. In this second turn of the discussion, Harald considered whether they could "find a case to apply" in all classes:

Ut	Who	What is said (translation)	What is said (original)
132	Harald	Is it possible for us to find a case to apply, where it really does not matter so much whether it is eighth, ninth or tenth grade?	Kan vi finne en eller annen case som vi kan prøve å løse som ikke er så nøye på åttende, niende eller tiende?
133	Gunnar	Do you think of, i…	Tenker du på, i..
134	Harald	[introduce]	[introdusere]
135	Gunnar	[Yes]	[Ja]
136	Harald	introducing Cabri. Perhaps to do something, trying to make this,	introdusere Cabri. Skal det være en eller annen ting, prøve å lage

		do so and so or something else? Because it is what we want to do on eight, ninth or tenth?	dette, gjøre sånn eller et eller annet? For det er det som vi gjør på åttende, niende eller tiende?
137	Elise	[Mm]	[Mm]
138	Harald	It is more basic, angles and such things, you do at grade eight?	Det er mer basic, vinkler og sånn, dere gjør på åttende?
139	Elise	[Eight, yes]	[Åttende, ja]
140	Harald	while we do (*interrupted*)	mens vi skal (*avbrytes*)

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 8

In the episode above, Harald for the second time in the meeting considered collaborative implementation of Cabri, at least presenting some grounding for such a one. However, then the discussion had what I interpret as an *important turn* when Frode and Jakob introduced the other teachers to their already planned arrangement for use of Cabri. Frode seemed to add on his comments presented in Episode 5 concerning possible common introduction, and he explicitly referred to a written *teaching package* which he and Jakob had *decided to use* in their teaching at Grade 8 (see Appendix 8v, p. 345). This teaching package is, in Section 6.1.1, considered as one of the teachers' arrangements for use of Cabri in teaching and was designed by Jakob's former colleague at the master programme at UiA, Bueie (see Section 5.4.1, p. 150). Neither Frode nor Jakob at this stage expressed any aims for their use this teaching package except that Frode argued that the package seemed *appropriate* to use in his class at Grade 8. Harald approved that the package could work as common starting point although it seemed as if he did not know the nature of it except for Frode and Jakob's description. Harald's suggestion of a common case applied at all grades was not followed up except for potential use of the teaching package suggested by Jakob and Frode. However, this package was only used at Grade 8. I have already considered the *input from Otto* in the form of a workshop at the school's computer lab (see Section 5.2.3, p. 135). This workshop session, which emphasised teachers' competences with Cabri and occurred one week after the commented school team meeting above, was later by the teachers argued as crucial in supporting implementation of Cabri both among the five teachers in the projects and their colleagues.

Despite teachers' efforts to have implementation of Cabri in all classes at Austpark, the only teacher outside the projects which implemented Cabri was Eivind at Grade 8. Thus, all the three teachers at Grade 8 implemented and orchestrated use of Cabri in their teaching in January 2006. In the end of Cabri-use interview (see Event 31), Frode addressed *benefits* with this *collaborative implementation* at *Grade 8* (see Episode 8 below). Frode emphasised that one of their achievements was that all the students at Grade 8 had got "the same training in geometry”:

Ut	Who	What is said (translation)	What is said (original)
112	Frode	Because it is such things that we have managed to succeed with on the grade that I am very satisfied with: That we managed to run it so equally.	For det er sånne ting vi har fått til på trinnet nå som jeg er veldig fornøyd med: Det at vi har klart å kjøre det så likt.
113	Ingvald	Mm	Mm
114	Frode	In all the classes. Every student on Grade 8 has got the same training in geometry	På alle klassene. Alle på åttende trinnet har fått den samme opplæringen i geometri.
115	Ingvald	[Yes]	[Ja]
116	Frode	regardless of the class where they are located. It is not always that we mange this at our school.	uansett hvilken klasse de er i. Det er ikke alltid vi får det til på skolen.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 8

The collaborative implementation of Cabri in mathematics teaching at Grade 8 was mentioned and emphasised several times by the teachers in reflection and feedback sessions in workshops in the projects. Later, in their conference presentation in September 2006 (see Event 38), Jakob and Frode reported from their implementation of Cabri and a *benefit* in managing to *include Eivind*, the third mathematics teacher at Grade 8 (see Episode 1 below). Similar to their “same training” claim in Episode 8 from the end of Cabri-use interview, to “do the same” in all the classes at Grade 8 was mentioned as an important benefit by the teachers during the conference. The teachers also referred to their participation in the projects as stimulating the collaboration at Grade 8:

Ut	Who	What is said (translation)	What is said (original)
12	Jakob	… Eivind has not participated (*refers to the KUL projects*), but he has been included in our work at the grade	… Eivind har ikke vært med (*viser til KUL prosjektene*), men han har blitt inkludert av vårt arbeid på trinnet.
13	Frode	And what is great, by being part of the KUL project and having the collaboration it involves, is that we finally at our school have managed to have some real collaboration, because it often ends with a kind of different teaching for students at the same grade. But now we have managed to do the same. And we will say more about the use of PCs, ICT later, but yes the differences between the classes have been minor.	Og det som har vært bra med, det at man har vært med i KUL og hatt det samarbeidet da, vi har endelig på vår skole fått til noe ordentlig samarbeid, det blir ofte kanskje litt ulikt tilbud for elevene på samme trinn noen ganger. Men nå har vi gjort likt og vi skal komme tilbake med litt av bruken av pc og data eller noe sånn, som, ja slik at forskjellen mellom klassene har blitt veldig liten.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 1

To summarise, analytical findings in this subsection indicate how the teachers at Austpark struggled and experienced resistance from other mathematics teachers at the school to implement Cabri and partly related to this did not manage to have a collaborative implementation within the group of teachers in the projects. A reason for this “partly claim” was their colleagues’ resistance which made it difficult for the 5 teachers in the developmental projects to implement Cabri since an aim at the school was to have similar teaching and use the same tests at each grade. Thus, it was difficult for some mathematics teachers at a grade to use Cabri and some not. Another reason could be Jakob and Frode’s decision to base their use of Cabri on a teaching package which they argued fitted well to the curriculum at Grade 8 and less suitable at Grades 9 and 10. This potentially made collaborative implementation at all grades harder since the teachers at Grade 8 wanted to use this package in most of their Cabri-lessons. The teachers at Grade 8 stimulated each other, worked together coping with issues, while the teachers at Grade 9 and 10 did not have this kind of collaboration with Cabri.

b) Students’ lack of free access to Cabri at home

In a number of workshops at UiA and conversations at the school, Jakob considered what he expressed as an unsatisfactory element with Cabri: the software requires a private licence to be run at students’ homes. Below I refer to a number of these sessions and how this issue of lack of access eventually led Jakob and Elise to run the free DGS GeoGebra[23] in their new Grade 8 classes, one year after Jakob and Frode’s initial implementation of Cabri.

The first time I overheard that the teachers considered *students’ access* to *Cabri* at *home*, was nine minutes into the school team meeting on the 7th of December (see Event 12) phrased as a question by Frode (see Episode 6 below). Gunnar, who had been involved when the school bought their school licence for Cabri, responded to Frode’s question by confirming that their students did *not* have free access to Cabri at home:

Ut	Who	What is said (translation)	What is said (original)
82	Frode	Will students have the possibility to have Cabri themselves?	Fins det noen mulighet for elevene å få Cabri selv?
83	Gunnar	No. If you should have such a school licence	Nei. Hvis du skal ha en slik skolelisens
84	Frode	[Yes]	[Ja]
85	Gunnar	then it costs twice as much as the one we have now. I think about 14 000 (*Norwegian krones*).	så koster den dobbelt så mye som den vi har i dag. Cirka 14 000 (*norske kroner*) tror jeg.

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 6

[23] GeoGebra is available on web: http://www.geogebra.org/cms/index.php?lang=en

After the episode above, the possibility of using the *demo version* was mentioned but considered as inappropriate because of its *limitation* of 30 days. Jakob contributed to the discussion arguing that students' lack of access to Cabri at home was substantial (see Episode 7 below). In utterance 114, Jakob said he believed, based on experience communicated by Otto, that access to Cabri at home would stimulate students' to work with mathematics serving as a motivating mathematical tool:

Ut	Who	What is said (translation)	What is said (original)
114	Jakob	I think the point considered by Frode is substantial. What I have heard about practical use of Cabri from Otto is exactly that students use the tool at home and spend hours and hours with the tool and learn a great lot and have real fun. So I actually think it is worth the money, all the good work that occurs at home. If I am able to light a fire (*means to motivate the students*) among them with a tool which they worked pleasantly with for hours	Jeg synes det er et vesentlig poeng det som Frode sier. Det jeg har hørt om praktisk bruk av Cabri fra Otto er at der er elever som bruker det timesvis hjemme og lærer massevis og har det kjempegøy. Da synes jeg faktisk at det er ganske mye verdt, all den gode jobbinga som skjer hjemme. Hvis jeg klarer å få tent gnisten (*mener her å motivere elevene*) hos de med et verktøy som de kan sitte og holde på med i timevis og kose seg med
115	Frode	[Yes]	[Ja]
116	Jakob	then I really think we could pay a lot for it.	så tror jeg faktisk at vi kunne betalt mye for det
117	Gunnar	Of course, it is not really a big amount of money. Actually it is a silly limitation.	Selvfølgelig, det er jo ikke store summen egentlig. Det er en tøysete begrensning.

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 7

Jakob and Frode's contributions indicate that they regarded lack of free access to Cabri as an *issue* for successful implementation of Cabri. Its importance is highlighted by the fact that Jakob and Frode many months later, at the school's KUL conference presentation in September 2006 (see Event 38), emphasised lack of student access to Cabri as a disadvantage and considered *alternative* DGS:

Ut	Who	What is said (translation)	What is said (original)
33	Frode	But what we experience. We may make this point right away: we consider alternatives to Cabri because of the big disadvantage that students do not have access to it at home because there is a licence problem….	Men det vi ser. Vi kan kanskje ta det nå med en gang: vi ser oss om etter alternativer i forhold til Cabri fordi den store ulempen er at elevene ikke har tilgang til det hjemme hos seg selv siden det var et program med lisens….

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 3

After a brief comment about the inappropriate limitation of the demo version, Frode offered the possibility that they will start to use other kinds of DGS instead of Cabri. Jakob described *reasons* for considering *alternative* software. In addition to *free access* for students and *availability* in the *Norwegian language* like Cabri, a new computer lab at Austpark which would be set up with ´*thin clients*`[24] were used as arguments for choosing GeoGebra:

Ut	Who	What is said (translation)	What is said (original)
36	Frode	I have found out that there are some other available which are free, Geonext, Geo	Jeg har funnet ut at det er et par andre som er gratis å få tak i, Geonext, Geo.
37	Jakob	[GeoGebra]	[GeoGebra]
38	Frode	GeoGebra.	GeoGebra.
39	Jakob	which we will consider to exchange to	som vi vil vurdere å gå over til.
40	Frode	But which is quite similar, is it not?	Men som er ganske likt, er det ikke det?
41	Jakob	Yes.	Ja.
42	Frode	You have made some testing?	Du har testet litt?
43	Jakob	I have tested a bit, I do think they can do much of the same	Jeg har testet litt, jeg tror de kan gjøre mye av det samme.
44	Frode	Yes.	Ja.
45	Jakob	They are also available in Norwegian (*means with Norwegian language*). They can be run in a browser, it is, Java software, so that is a real benefit. And Cabri, after what I have heard, cannot be run on thin clients, so, it will be, since we receive a new computer lab with thin clients, we will not be able to use Cabri there. Thus, we consider another dynamic geometry software package.	De finnes også på norsk (*mener med norsk språkfil*). De kan kjøres i en nettleser, det, Java-programmet, så det er jo en fordel med det. Og Cabri, etter hva jeg har skjønt så kan du ikke kjøre det på tynne klienter, så, det blir jo, i og med at vi får et nytt datarom med tynne klienter, så vil vi ikke kunne kjøre Cabri der. Derfor vurderer vi å gå for et annet dynamisk geometriprogram

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 4

During a plenary in ICTML Workshop 10, two and a half months later, Jakob confirmed that he and Elise at Grade 8 had started to *implement GeoGebra* and would use it in teaching after Christmas:

Ut	Who	What is said (original)[25]
38	Jakob	…We will implement GeoGebra at Grade 8 at Austpark to consider it compared to Cabri…

Event 39, Nov 29th 2006, UiA, ICTML Workshop 10, Video, Episode 1

[24] A thin client is a technical solution in the teaching district where computers are used as terminals, with all software on a central server. This technical solution gives problems for some software to run because of limited bandwidth.
[25] This part of the plenary was held in English language.

A few seconds afterwards he explicitly referred to one of the advantages he emphasised in the conference presentation; that GeoGebra is *free*:

Ut	Who	What is said (original)
40	Jakob	…One of the advantages with GeoGebra is that it is free….

Event 39, Nov 29th 2006, UiA, ICTML Workshop 10, Video, Episode 2

In this subsection, I have considered the *issue* with lack of free access for students to use of *Cabri* at *home.* The issue was raised in a school team meeting ahead of their use of Cabri in teaching and emphasised several times after their teaching with Cabri came to an end. The issue energised a shift of DGS to GeoGebra, which is a freeware accessible either on web or downloaded locally on a computer and thus not encumbered with access problems. One year after their implementation of Cabri, GeoGebra was used in teaching in Jakob and Elise's Grade 8 classes at Austpark.

c) Access-priority to computer lab at Austpark

The third issue I consider is related to local allocation to computers at Austpark. *Access-priority* to the big computer lab at Austpark was rasied as an issue and discussed ahead of and part of their implementation of Cabri. During the 26th of October-meeting at Austpark, the teachers considered criteria for *priority* to the computer lab (see Episode 6 below). Gunnar referred to frustration concerning limited access to the computer lab during the previous year, where other teachers' *early bookings* and the *courses* held at the lab were mentioned as reasons for low access:

Ut	Who	What is said (translation)	What is said (original)
373	Gunnar	I just need to say. There was frustration last year. During your planning you find a wish for using the computer lab but then it is not possible. It is booked by others long time ago. Or there are suddenly some courses, so you can not be in the computer lab every second, third week. It is about the organising.	Det må jeg jo bare si. Det var jo frustrasjon i fjor. Så går du inn og planlegger at nå vil du på datarommet så går det ikke. Det er tatt opp av andre lang tid på forhånd. Eller så er det plutselig noe kurs, du får ikke vært på datarommet annen hver uke, tredje hver uke. Det har med organiseringen å gjøre.

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio, Episode 4

The access was very limited in periods because the *school* had *decided* to give all their students *general training* in use of Microsoft software packages and Internet based on established software courses for trade. In the episode below, the benefits of these courses, in for example Excel, was *questioned* and two disadvantages were mentioned: The courses *monopolised* the computer lab for long periods, and many classes at the school did *not* use the software after the course. Harald also questioned the pedagogical values of such courses claiming that they were *waste of* *time*. This seems to be a similar view as expressed by Otto (see Section 5.2.3, p. 134), and the vice principal responded by arguing for an evaluation:

Ut	Who	What is said (translation)	What is said (original)
397	Harald	This is a pedagogical question. Because here we disagree	Dette er et pedagogisk spørsmål. For her er vi uenige
398	Aud	Yes it is	Ja det er jo det
399	Harald	Because I believe that it is almost time thrown away. Several of these classes which work with Excel never use it more	For jeg mener jo at dette er nesten bortkastet tid. Det er flere av disse klassene som er gjennom Excel som aldri bruker det mer.
400	Aud	At least it is (*interrupted*)	Iallfall er det (*avbrytes*)
401	Harald	It is a waste of time	Det er bortkastet tid
402	Vice principal	Then we need to evaluate it	Da må vi ta en evaluering på det

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio, Episode 5

In the school team meeting six weeks later (see Event 12), Gunnar reported from a follow-up meeting with the principal at Austpark concerning regularly use of the computer lab (see Appendix 8vi, p. 346). Gunnar commented their desired access-priority to the computer lab saying "he did write it down". By this comment Gunnar referred to the principal's action when he wrote a notice on a paper that the mathematics teachers wanted access to the lab. Shortly after this school team meeting in December, the five teachers in the projects booked computer labs for teaching in several weeks after Christmas and also tried to stimulate the other mathematics teachers to do the same. Later, both in the workshops in January 2006 and below in Episode 7 from the end of Cabri-use interview in March, the *pre-booking* of computer labs was reported as a factor which stimulated their implementation process of Cabri:

Ut	Who	What is said (translation)	What is said (original)
88	Jakob	Then Frode and I found available time on the computer lab.	Så tok Frode og jeg og fant fram når det var ledig på datarommet.
89	Some	Mm	Mm
90	Jakob	and distributed to mathematics	og fordelte ut til matematikk
91	Frode	Mm	Mm
92	Jakob	when the different persons had mathematics and we used Cabri.	når de forskjellige hadde matematikk og da brukte vi Cabri.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 7

The early booking of the computer lab was also mentioned as a factor for success in implementing Cabri at Grade 8 during their conference presentation in September 2006. Frode, in Episode 5 (see Appendix 8vii, p. 346), argued that a consequence of their early bookings was that "we pushed ourself into an emphasis on it".

Seeing this in a time perspective (for an overview of meetings I refer to Table 5.4, p. 147), during the school team meeting with the vice principal in October 2005 the issue concerning over booked computer labs was raised. Two reasons mentioned were other teachers' early bookings and the courses in use of computer software which occupied the computer lab. The teachers followed up by arguing for access-priority to computer labs in meetings with the vice principal, and did early bookings which altogether emphasised both a readiness and a commitment to implementation of Cabri.

d) Priority on geometry by reserving extra time

Teachers' emphasis on *time as in issue* when considering changes or development in teaching is often reported in research papers. The quoted paper by Assude (see Section 2.2.4, p. 39) discusses teachers' concern for time in a setting with introduction of Cabri.

In the end of Cabri-use interview, Frode referred to the decision made concerning *priority* on *geometry* at Grade 8 (see Episode 5 below). Their commitment to have priority on geometry and their endeavour on Cabri, are supported by Frode's comment in utterance 83 where he argued that they "reserved *extra* time" on the geometry in their teaching.

Ut	Who	What is said (translation)	What is said (original)
81	Frode	Yes. And we decided to make priority on geometry	Ja. Så bestemte vi oss for å satse på geometri
82	Jakob	Mm.	Mm.
83	Frode	And reserved extra time for it.	Og satte av ekstra tid til det.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 5

This is very close to what Frode said two months earlier in LCM Workshop 10 (see Event 16, Episode 6 below). The workshop occurred just a few days after Jakob and Frode's first ever lessons with Cabri. In utterance 121, Frode referred to a number of teachers at Austpark as *we*, and he emphasised that their priority on geometry and use of Cabri were accomplished by spending *more time* on the topic and by *early bookings* of the computer lab:

Ut	Who	What is said (translation)	What is said (original)
119	Frode	We wanted priority on geometry.	Vi ville satse på geometri.
120	Ingvald	Yes.	Ja.
121	Frode	We reserved extra time too. But now every class will do it (*refers to use of Cabr*) so all of us booked time at the computer lab. We basically have one hour at the computer lab each week	Vi satte av mer tid til det også. Men nå skal jo alle våre klasser gjøre det (*viser til bruk av Cabri*) så vi har satt av tid på datarommet vårt. Vi har i utgangspunktet bare en time i uka
122	Ingvald	Mm.	Mm.
123	Frode	on the computer lab. Added what you are able to find of free time.	på datarommet. Pluss det du klarer å få til deg av ledig tid.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 6

The commitment to their *objects with Cabri* (see Section 3.1.2, p. 62) is strengthened with their choice to reserve extra time for teaching the geometry topic in their curriculum. In the episode above, Frode repeatedly referred to "we" but to whom is he referring? All the teachers at Austpark, all the mathematics teachers at Austpark, the five mathematics teachers who participated in the projects or the three mathematics teachers at Grade 8? In the LCM/ICTML focus group interview, two and half months later, Frode also referred to *we* (see utterance 35, p. 151). The discussion afterwards then indicated that *we* were the five teachers in projects. As the first issue considered in this section (5.4.2) indicates, the teachers regarded inclusion of the other mathematics teachers to be crucial as well. For example, in order to be able to give the proposed similar teaching to all their students, Frode argued that inclusion of other mathematics teachers at the grade were of necessity.

e) Lack of testing outcome of Cabri teaching

A fifth issue considered by Jakob and Frode (see p. 154), was lack of *testing* students' abilities to utilise Cabri both in mathematics tests in schools as well as in the national examination at Grade 10. The role of assessment driving teaching and experienced as an issue for teachers when asked to implement ICT in teaching is considered in Hennessy et al. (2005). They refer to countries where policy makers either require or permit (like in Norway) use of calculator and computing resources in written examinations while many countries do not. Overall, Hennessy et al. argue for the big challenge teachers meet when asked to integrate ICT in teaching within existing National Curricula and assessment regimes. Monaghan (2001) emphasises teachers' concerns for obligation to their students when being asked to spend time on ICT not assessed in tests:

> ..saw their practice as supporting external curriculum and assessment criteria and felt a moral obligation to their students that ICT work had to support learning which would be assessed without ICT (Monaghan, 2001, p. 389).

When considering implementation of Cabri in the school team meeting on the 7th of December, Frode paid attention to how use of Cabri could be included in their tests (see Episode 3 below). When considering tests with Cabri, Frode referred to the issue raised in the previous section: The need for *access to computer labs*. Gunnar responded by referring to the *lack* of implementing Cabri (and other kinds of DGS) in the *national examination test* in mathematics at Grade 10:

Ut	Who	What is said (translation)	What is said (original)
37	Frode	Thinking of the spring, how will the tests look like? What about geometry tests, will we need access to computer labs	Hvordan blir prøveformen når vi kommer til våren? Hva med geometriprøver, skal vi da ha tilgang på datarom
38	Jakob	[Mm]	[Mm]

39	Frode	in order to solve such tasks? Or not (*interrupted*)	for å løse sånne oppgaver? Eller skal vi ikke (avbrytes)
40	Gunnar	That is the point. Things are commanded by rigorous conditions. If we use test from the Norwegian Directorate for Education and Training, where they use compasses and ruler, it is difficult to do anything else	Det er jo akkurat det. Det blir styrt av litt sånn rigide forhold. Hvis vi får prøve fra Utdanningsdirektoratet, hvor det legges opp til passer og linjal, så er det jo vanskelig å få til noe annet

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 3

The discussion continued with Gunnar communicating what he knew about the process of incorporating Cabri in the national mathematics tests in Norway, with some inputs from Aud. Then Harald expressed a comment indicating *hopelessness* with Cabri when students were not allowed to use the tool in the national test (see Episode 4 below). Gunnar contributed by referring to comments from Otto pointing to *positive experience* for students' abilities to apply *compasses after* first been working with *Cabri*. In utterances 51-53, the teachers returned to an earlier posed question in the meeting by Frode. The question emphasised whether the teachers at Austpark wanted a priority on Cabri and less focus on compasses. In utterance Jakob 54 continued the emphasis on tests considering how they locally at their school could *organise tests* for several classes with Cabri on the computer lab. Harald and Elise reacted by mentioning their equivalent organising experience with use of the spreadsheet package Excel in tests:

Ut	Who	What is said (translation)	What is said (original)
48	Harald	But I understand that the issue was raised there (*refers to a national conference in Trondheim*). It does not help much to practice on this (*refers to Cabri*) if not the examination	Men jeg forstår at der ble det problemet presenteret (*viser til en nasjonal matematikkonferanse i Trondheim*). Det hjelper lite om vi har trent på dette (*refererer til Cabri*) hvis ikke eksamen
49	Gunnar	Otto once said that for students starting to use Cabri, the transition to work with compasses and ruler is not so hard. He said. So it could be an advantage to work with Cabri first. But it is really a question for us what we want?	Otto sa en gang at for elever som begynte med Cabri, var ikke overgangen til å jobbe med passer og linjal så svær. Sa han. Så det var kanskje en fordel å jobbe med Cabri først. Men det er jo spørsmål om hva vi vil?
50	Frode	Yes	Ja
51	Gunnar	Wether we want to be a school not using ruler, we have to go for it. I think we will be able to do it.	Vil vi være en skole som ikke bruker linjal, så må vi jo gå for det. Vi kan jo sikkert få det til
52	Frode	Yes, I am sure we can manage it but I am considering whether it is sensible	Ja, vi kan nok få det til men jeg bare lurer på om det er lurt

53	Gunnar	Yes, is it?	Ja, er det det?
54	Jakob	Two things. If we want to run tests with Cabri, we have to make sure the year examination is organised in time so each classes can be on the computer lab and finish the part with Cabri there.	To ting. Hvis vi skal begynne å kjøre prøver med Cabri, må vi passe på at vi organiserer tentamen sånn at innenfor det og det tidsrommet har den og den klassen tilgang til Cabri og være der og gjøre Cabridelen ferdig.
55	Harald	Yes, like we did with Excel	Ja, vi hadde det sånn med Excel
56	Elise	[Mm]	[Mm]

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 4

Their desired need to design tests with Cabri was followed up, and is considered as a being part of their arrangements for use of Cabri at Grade 8 (see Section 6.1.2). During the winter 2006, Jakob and Frode designed and used a geometry test with Cabri in their three classes at Grade 8 which also was used by Eivind teaching the final fourth class at Grade 8. The test is available as Appendix 5c) and discussed in Chapter 6. In the school's end of year mathematics examination at Grade 8 in May, one hour of the test was reserved to a computer software test which included one problem to be solved with Cabri and one with Excel.

I interpret Frode and Jakob's efforts to design and use Cabri-tests as an indication of their desired *outcome*: To have Cabri *integrated* in the geometry teaching at Grade 8 and not only something "extra". During a group session in LCM Workshop 10, which took part in an early phase in their Cabri-teaching (see Event 16), Frode referred to their design and implementation of Cabri in tests as *essential* for his implementation of Cabri (see Episode 11 below). He explicitly argued that "year examination must reflect the teaching" indicating that he did not see any point of using Cabri at all if testing of students' outcome did not occur:

Ut	Who	What is said (translation)	What is said (original)
224	Frode	The challenge for us now will be to design a year examination	Utfordringen nå for oss blir jo det å kunne lage en årsprøve
225	Some	[Mm]	[Mm]
226	Frode	where this (*refers to Cabri*) is part of the test.	der dette (*refererer til Cabri*) er en del av prøven
227	Some	Mm.	Mm.
228	Frode	because if not I do not think it is any point.	for hvis ikke så synes ikke jeg det er noe vits altså.
229	Some	No.	Nei.
230	Some	Yes.	Ja.
231	Frode	Year examination must reflect the teaching.	Tentamen skal reflektere undervisningen.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 11

The importance of including use of Cabri in tests was strengthened by

Harald's contribution shortly afterwards where he expressed the situation at *Grade 9* almost as a *paradox*. For Harald, the issue with lack of having Cabri included in tests at Grade 9 and the national final examination at Grade 10 was bothering him, but he was not so determined that it stopped his implementation of Cabri.

Ut	Who	What is said (translation)	What is said (original)
241	Jakob	It is me and Frode and Eivind who teach at Grade 8 and we are all using Cabri	Det er meg og Frode og Eivind som underviser på åttende trinn og alle tre bruker Cabri
242	Harald	[Well]	[Altså]
243	Harald	we will not mange to have similar tests, but it is	vi får ikke til å ha lik prøve, men det
244	Frode	No	Nei
245	Some	[a challenge]	[det er en utfordring]
246	Frode	that we practice on this	at vi øver på dette
247	Some	[Mm]	[Mm]
248	Harald	while the examination looks different.	mens eksamen er annerledes.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 12

The *issue* concerning *lack* of *testing* students' ability in using Cabri was addressed by the development of formal *tests* at Grade 8. Jakob and Frode successful efforts, to convince the third mathematics teacher at Grade 8 to implement Cabri, resulted in a possibility to have a collaborative test for all the classes which included use of Cabri. Jakob and Frode designed both a geometry test and an end of year examination test at Grade 8 which included use of Cabri. Thus, the teachers at Grade 8 overcame the issue concerning lack of testing outcome of Cabri-teaching locally at Austpark.

5.4.3 Summary

Based on analytical findings, I ended Section 5.4.1 by listing *six main reasons* for teachers' implementation of Cabri (see p. 154). These were the school's Cabri-licence, their participation in the developmental projects, Jakob's inclusion in the school team, a desire to do something new as a group and a possible utilisation of both Cabri and compasses in teaching. In Section 5.4.2, I argue that *five main issues* were considered by the teachers in their implementation process (see p.154). These issues were their collaborative efforts to implement Cabri at Austpark, students' lack of free access to Cabri, access priority to computer labs, reserving extra time and lack of testing outcome of Cabri-teaching.

During the end of Cabri-use interview in March 2006, Harald and Frode referred to Jakob's entrance to the school and Grade 8, in August 2005 as his first full teacher job, to be crucial for implementation of Cabri at Austpark. What made Jakob's entrance that important and potentially explains the *collaborative implementation* at *Grade 8*? Jakob had experience with Cabri from his General Teacher Education programme and from a former colleague in education who had designed a teaching package, and Frode was an experienced mathematics teacher at Austpark who expressed a desire to do something "new" (see Section 5.4.1, p. 148). Could it be that together they were a perfect match of experience in teaching and in using Cabri? This is speculation and difficult to substantiate. In Section 5.6.1, the issue of lack of inclusion of Cabri in the national examination at Grade 10 and the closeness to this at Grade 10 and Grade 9 is offered as another possible reason for this difference as well as Jakob and Frode's co-ordinated use of compasses and Cabri.

In the case considered in this thesis only Jakob and Frode have been included from Austpark. But as presentation of data have shown in the previous sections and later in Chapter 6, Harald, Gunnar and Elise contributed in school team meetings and interviews at the school and in workshops at UiA. Thus, their contributions have been included as part of the analysis both in this chapter and Chapter 6.

5.5 Trude's implementation of Cabri

As considered later in Chapter 6, Trude wanted her students to *investigate* and *solve tasks* in geometry by using Cabri. She also referred to how she *encouraged* her students to *help each other* during the lessons. But what were Trude's reasons for implementing Cabri in her teaching and what kinds of issues did she consider in her implementation process?

Section 5.5 and its subsection (5.5.1) have a brief content. I only consider three events as illustrated in Table 5.5:

Table 5.5: List of events considered in Section 5.5.1

Event	Date	Type of sessions
1	26.01.2005	ICTML Workshop 3 at UiA
16	11.01.2006	LCM Workshop 10 at UiA
21	18.01.2006	ICTML Workshop 7 at UiA

Why do I consider so few events compared to the much larger number of events considered in the analysis of Jakob and Frode's implementation of Cabri? A *first* reason is that Trude's interest in implementing Cabri was unknown for didacticians until she in LCM Workshop 10 reported from her first ever lesson with Cabri. Thus, implementation of Cabri was not discussed in any of the school team meetings at Fjellet during autumn 2005 and didacticians were not part of any discussions about her implementation of Cabri beside some discussions in a plenary during ICTML Workshop 3 (see Event 1). Since Trude had a break from teaching in March and out the school year 2006, she was not part of the LCM/ICTML focus group interview at Fjellet where issues and reasons for her implementation could have been discussed. A *second* reason for the few pages presented about Trude's implementation of Cabri is the claim I offer in this section about what seemed to have been much fewer issues and reasons considered by Trude in her implementation of Cabri.

5.5.1 Reasons and issues considered by Trude

Trude was asked by Aud, already in ICTML Workshop 3, whether she had "acquired the necessary input to dare to use it in your class?" (see Section 5.2.1, p. 124). In that session, Trude responded arguing that she found it necessary to reserve time. In Section 5.2.1, I argued that by this comment she paid attention to a needed "preparatory phase in her *implementation* process as well as the use of Cabri in teaching".

During two workshops almost a year later, both occurring in January 2006 (see Table 5.5), Trude informed didacticians about her implementation of Cabri in her class at Grade 8. Below I argue that *expressed expectations* from her participation in the *developmental projects* and *statements* in the National Curriculum appeared to be two important and related reasons for her implementation of Cabri. When analysing her Cabri-teaching in Chapter 6, it is also evident that, like Jakob and Frode, she took advantage of using *both Cabri* and *compasses* when working with the geometry topic. This seems to have been important in her implementation process since she believed her students would be able to work quite independently with Cabri because of their background with use of compasses on related geometrical work. Although Trude did not mention it, the school's newly bought and installed *school licence* for Cabri probably contributed as a reason for her efforts to implement Cabri.

In Episode 1 from ICTML Workshop 7 (see Event 21), Trude expressed her *desire* to start using Cabri (presented in Section 5.2.4, p. 138). It was based on what I there argued to be an *expressed expectation* phrased as "I just have to do it". The same episode illustrates how she enthusiastically reported from her first ever use of Cabri in teaching 12 days earlier. During the LCM workshop one week earlier (see Event 16), she emphasised her own *lack of skills* in using Cabri as an *issue*. It seems like Trude wanted her students (and didacticians) to be *aware* of her own experienced lack of skills in using Cabri in teaching:

Ut	Who	What is said (translation)	What is said (original)
27	Trude	And then I just said (*refers to what she said to her students*) that I am not very clever in this (*refers to Cabri*), far from good on it	Og så sa jeg bare (*refererer til hva hun har sagt til elevene sine*) at jeg kan det (*refererer til Cabri*) ikke ordentlig kan det langt fra ordentlig.
28	Some	Mm	Mm
29	Trude	So we try…	Så vi prøver…

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 3

In the earlier quoted utterance 176 in ICTML Workshop 7 (see Section 5.2.4, p. 138), Trude reported how she had experienced a pressure to implement Cabri referring to as a “kick in the back end”. Despite her expressed weak skills in Cabri and other kinds of computer software, she had been able to *dare* to start using Cabri which she expressed with a great relief. In utterance 178 from the same workshop (see Episode 4 below), Trude referred *proudly* to her teaching with Cabri and to her contribution in LCM Workshop 10 in which the episode presented above reports from. The combination of her expressed lack of skills in using Cabri and how she expressed the commitment from the project, illuminate that implementation of Cabri was a big *issue* for her and consequently a big victory for herself to manage.

Ut	Who	What is said (translation)	What is said (original)
178	Trude	… It was **such a** lesson and it, it went equally well in the lesson afterwards. So I (…) I really shouted loudly being able to do a proper job. And then I came here and reported it…	… Det var **den** timen og det det gikk like bra på de andre etterpå. Så jeg kom jo (…) jeg jublet skikkelig for det nå har jeg gjort en god jobb. Så kom jeg her og fortalte det …

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 4

As evident from this brief section, Trude’s reasons and issues considered when implementing Cabri seemed different from Jakob and Frode’s considered in Section 5.4. Trude’s issues were much more personal and related to dare implement Cabri despite her own experienced weak skills in using Cabri and other kinds of computer software tools. Trude reasons for implementing Cabri also seemed to be more influenced by expectations experienced from her participation in the ICTML project. Issues related to her school were not expressed. Comments in the LCM/ICTML focus group interview in March 2006 by her colleague Markus indicate that the three mathematics teachers at lower secondary level at Fjellet met a different kind of school institutional issue compared to the mathematics teachers at Austpark. In Section 7.3.3 I suggest that as mathematics teachers, the teachers at Fjellet were left more on their own and had very little subject collaboration with other mathematics teachers at the school. Although I never observed Trude making this point, it might explain why I consider the issues she addressed were personal. The differences in reasons and issues considered by Jakob, Frode and Trude will be analysed further in Sections 5.6 and 5.7 when discussing teachers’ motives and considering their goals for implementing Cabri.

5.6 Analysis of teachers' motives for implementing Cabri

In Section 5.1 I presented three activity systems which I consider in the activity theory analysis in this chapter. In Section 5.3 I analysed how teachers experienced the *external support* by didacticians in the developmental projects. Didacticians gave support by emphasising utilisation of Cabri in geometry teaching which particularly Trude experienced as giving expectations for development in teaching. Using activity theory notions, the support proposed a motive serving as object and a particular mediating artefact in each teacher's teaching activity system.

Analytical findings concerning teachers' reasons for implementing Cabri and issues considered in their implementation process of Cabri have been presented in Sections 5.4 and 5.5. In Sections 5.6.1 and 5.6.2, teachers' *motives* for implementation of Cabri are discussed by analysing the different issues raised and addressed by the teachers. In the analysis, I consider relationships within the upper level in Leont'ev's activity theory level model (see Section 3.1.2, p. 61): between *motives* serving as *objects* for Cabri (see the bullet points, p. 62) within their teaching activity systems. Furthermore, how *tensions* within their school activity system led to *contradictions* and possible *expansive development* of *collective objects* for teaching within their teaching activity systems. The role of these terms in the analysis was considered in Section 3.1.5 (see p. 69), and have already been utilised in Section 5.3 with concerns for the external support (see p. 143).

Sections 5.6.1 and 5.6.2 demonstrate indications of such *external* influence on objects within the teaching activity system due to teachers' participation in the ICTML project, which is elaborated further in Section 5.6.3. The activity theory analysis in Sections 5.6.1 and 5.6.2 indicate:

- Jakob and Frode's implementation of Cabri were dominated by several *school* related reasons and issues.
- Trude's implementation of Cabri was dominated by *personal* oriented reasons and issues.

In Chapter 2 I referred to a list of *contextual* and *personal* factors (see Section 2.2.4, p. 42) influencing teachers' implementation process of ICT in mathematics teaching suggested by Crisan et al. (2007). Thus, the contextual factors seemed to have dominated Jakob and Frode's implementation process, while Trude's implementation was dominated by the personal factors supported by expectations from didacticians in the ICTML project.

5.6.1 Jakob and Frode's school related reasons and issues

Why was Cabri implemented by Jakob, Frode and their colleague Eivind at Grade 8? Based on analytical findings presented in Section 5.4.1, I discussed and listed six main reasons (see p. 154). In the summary in Section 5.4.3, these reasons were summarised as "the school's Cabri-licence, their participation in the developmental projects, Jakob's inclusion in the school team, a desire to do something new as a group and a possible utilisation of both Cabri and compasses in teaching"(see p. 168).

I argue that teachers' "desire to do something new" in their mathematics teaching is important when I discuss their motives and goals for implementation of Cabri. During the school team meeting at Austpark in October 2005, Jakob for the first time introduced the didacticians to his and Frode's initial plan for implementation of Cabri which included use of Cabri in teaching early in January 2006. In the following school team meeting on the 7th of December, Frode asked the question whether Austpark wanted to be a school that used Cabri and not compasses. He used the terms *modern* tool versus the tools of yesterday. Later, when he described why they implemented Cabri, he referred to a "desire to do something *new* in mathematics teaching" (see utterance 52 from the end of Cabri-use interview in March 2006 presented on p. 148). By raising the question about use of Cabri as a modern tool in the school team meeting, he stimulated a discussion which raised several *issues* for their school activity system. His and his colleagues' efforts to raise and address issues stimulated *expansive development* concerning implementation, orchestration of Cabri-use and students learning of geometry as a collective object within their school activity system and thus potentially for their teaching activity systems. Related to Frode's question and discussion in different meetings, interviews and workshops, Section 5.4.2 illuminated a total of *five main issues* concerning implementation of Cabri (labelled a-e). The same list of issues is repeated below and analysed one by one utilising activity theory. I have added *teachers' own competences in using Cabri* as an issue although this issue more relates to teachers' *use* of Cabri in teaching.

a) Collaborative work and implementation of Cabri at Austpark.
b) Students' lack of free access to Cabri at home.
c) Access-priority to computer labs at Austpark.
d) Time on the geometry topic.
e) Lack of testing outcome of Cabri teaching.
f) Teachers' own competences in using Cabri.

The main period of Jakob and Frode's implementation of Cabri was autumn 2005 followed by their orchestration of Cabri-use in teaching starting early in January 2006. Two school team meetings in autumn 2005, on the 26th of October and on the 7th of December, workshops both before and after their Cabri-use in teaching in January 2006, and the two interviews with the teachers at Austpark in March 2006 are all crucial events in my study of their implementation process.

a) Collaborative work and implementation of Cabri at Austpark
This issue refers to the difficulties experienced by the five teachers at Austpark when trying to inspire and support the other mathematics teachers at the school to implement Cabri. Also within the group of the 5 teachers in the projects, *objects* and desired *outcomes* when implementing Cabri within their teaching activity systems varied. As already emphasised, Frode, Jakob and the third mathematics teacher at Grade 8 implemented Cabri, the same written teaching package and tests in their teaching. Gunnar and Harald at Grade 9 each implemented Cabri in their teaching but none of their colleagues at Grade 9 or any of the mathematics teachers at Grade 10 did. Harald and Gunnar used Cabri without any collaboration concerning instruction materials, such as tasks or teaching packages, and none of them used tests which included use of Cabri.

Didacticians in the KUL activity system made efforts both to constitute and make sure that the work in the school teams, one of the desired outcomes in the LCM project, became an efficient community for teachers in the projects. In the school activity system at Austpark, *all* the teachers at *each* grade independent of school subjects constituted separate communities expected to work collaboratively. Hence, the desired outcome in the LCM project that the five teachers constituted a team supposed to work together, provoked a tension for the established community in the school activity system. The *rule* for collaboration among the teachers at Austpark was related to each grade and included all subject teachers at the grade. When didacticians within the KUL activity system wanted a number of mathematics teachers to work together as a community, it provoked a *tension* for the communities in the school activity system at Austpark since the community of project teachers was *mathematics* based and *across grades*.

To work across the grades with other mathematics teachers was not a new idea for the teachers. In the LCM/ICTML focus group interview at Austpark in March 2006, the teachers referred to a mathematics conference in 2004 which had inspired themselves and their principal to constitute a group of mathematics teachers at Austpark. This group included in the start Harald, Gunnar and after a while Elise and Frode. The fact that the school invited themselves into the project, confirms that there was *no big tension* to the idea of working as a team of mathematics teachers. In the focus group interview, the teachers claimed that they hoped that their participation in the projects would lead to increased collaboration in mathematics teaching at Austpark. Frode also explicitly referred to improved learning with better achievements by their students as a desired *outcome*. Their struggles with having their own school teams in the projects to work, to include the other mathematics teachers and to work in the suggested grade levels at their school remained *ongoing issues* within their school activity system. The support and expectations concerning their work as a group where didacticians in school team meetings also emphasised lack of contract fulfilment, substantiate this as a strong issue serving as a tension at the school.

Already in the school team meeting in October 2005, Jakob confirmed that he and Frode planned to use Cabri after Christmas. In the school team meeting at Austpark some weeks later on the 7th of December 2005, Harald offered the idea of using Cabri in *similar ways* at all the three grades which offered a tension for the established grade-communities at Austpark. In utterance 71 (see Section 5.4.2, p. 156), Harald said: "Maybe we could try to do something jointly, study how we carry it out and then evaluate it afterwards…". Frode quickly questioned whether it would be reasonable to do it in a similar way at all grades, and then in utterance 141 (see Appendix 8v, p. 345) confirmed that he and Jakob planned to use a teaching package in most of their lessons at least in the start. It later became clear that neither Gunnar nor Harald at Grade 9 chose to use this teaching package. When I later consider the content and teachers' use of the teaching package (see Section 6.1.1), one of the findings is that the package was designed to fit well into the National Curriculum for the geometry topic at Grade 8. Therefore, the written teaching package supported the object for the teachers in the school activity system at Grade 8 well.

As already emphasised in the analysis, at least Frode emphasised the importance of having Cabri included in testing which was only possible if all the mathematics teachers at a grade used Cabri. Use of the same package supported an outcome for him which seemed to be a kind of *rule* in their school activity system: That all the students at a grade are taught in a similar way. Frode emphasised this both in Episode 8 (see Section 5.4.2, p. 158) in the end of Cabri use interview in March 2006, and again half a year later in utterance 13 in Austpark's presentation at the KUL conference: "And what is great, by being part of the KUL project and having the collaboration it involves, is that we finally at our school have managed to have some real collaboration, because it often ends with a kind of different teaching for students at the same grade. But now we have managed to do the same." Frode's great pleasure expressed in this session indicates that their implementation of Cabri including tests served as an *object* and supported their ways of testing *outcomes* for his teaching activity system. He also appreciated the collaboration among the mathematics teachers which he saw as an important outcome supporting the development of collective object in the school activity system at Grade 8. Thus, their discussions in school team meetings and conversations between Jakob and Frode concerning implementation of Cabri had provoked a tension within the established community stimulating a *contradiction* and *expansive development* for the mathematics teachers at Grade 8 with the following collective object (see Figure 5.2, p. 186): "Implementation and orchestration of Cabri-use in the geometry topic, building on use of compasses, with students' learning related to requirements in the Curriculum".

Already in ICTML Workshop 4 in April 2005 (see Event 1), Gunnar, expressed frustration about *resistance* among colleagues to implement Cabri (see Episode 1, p. 155). Aud then responded by referring to general statements in the curriculum concerning use of computer software. I consider this as a didactician's support of the use of Cabri as a *collective object* within their school activity system. However, the problem for Gunnar seemed to have been to convince his colleagues to implement Cabri despite a number of issues and lack of interpreting the potential in Cabri to respond to statements in the Curriculum. At Grade 8 they overcame a number of these issues, and the workshop session with Otto on the 14th of December was another step in the process of involving the other teachers. However, during the end of Cabri-use interview in March 2006, Frode expressed some disappointment with the slow progress in the implementation at other grades than Grade 8. Their desire to succeed in implementing Cabri in every class at the school and working together seemed to have been a much preferred *outcome* for the teachers which Harald expressed in the following way in the interview: "It was not only one who had to do it on his own but we were several who wished to try" (see utterance 62, p. 150). This indicates some of the teachers' *readiness* for *development* at Austpark.

b) Students' lack of free access to Cabri at home

The issue about students' lack of free access to Cabri at home was raised by Frode in a school team meeting one month ahead of his and Jakob's initial Cabri-use in teaching in January 2006. Gunnar replied by confirming a no to the question of general access except for the possibility to use a limited demo version. Jakob responded by emphasising a motivational effect of having access to Cabri at home (see utterance 114, p. 160), and raised this lack of free access as an issue which he repeated in several events afterwards. In their school's conference presentation in September 2006, Frode argued that the teachers at Austpark wanted to consider alternatives to Cabri. In utterance 37 (see p. 161) Jakob mentioned GeoGebra as their potential choice. In utterance 45 he argued for benefits with GeoGebra mentioning that GeoGebra was free, could be used at their old computer lab and the new computer lab with thin clients, and like Cabri was available in Norwegian language. During ICTML Workshop 10 in November 2006, Jakob confirmed that he and Elise had decided to use GeoGebra in their new Grade 8 classes and they used GeoGebra in their teaching in Jaunary 2007.

Thus, one year after implementing Cabri, they exchanged DGS package from Cabri to GeoGebra. By this change they overcame the issue related to students' access to the *mediating artefact*. One year earlier, in the school team meeting in December 2005, Jakob referred to students' increased efforts and motivation to mathematics as a desired *outcome* which he thought would be released by free access to the software (see Section 5.4.2, p. 160) . The lack of access at home was brought up many times as an issue, and worked as a tension for Jakob's teaching activity system. This tension eventually energised a *contradiction* and *expansive development* within his and Elise's teaching activity systems and the school activity system at Grade 8 shifting from Cabri to the freeware GeoGebra.

c) Access-priority to computer labs at Austpark

Discussions concerning access-priority to computer labs were central in both the school team meeting in October and in December. During the meeting in October, the teachers expressed frustration related to other teachers' early bookings and general training courses held at the computer lab which monopolised the computer lab and made frequent use of computer software difficult. In the meeting, the school's access-priority and decision to have priority on general training courses in use of computer software was discussed. In utterance 397 (see p. 163), Harald expressed critical remarks concerning the pedagogical value of these courses and later added how the courses monopolised the computer lab for long periods of time. The teachers expressed critical comments to *the division of labour* by considering judgements made by the people managing the *rules* which guided access-priority to computer labs within their school activity system. Teachers' comments indicate that they experienced lack of access to computer lab as an issue for possible implementation of Cabri within their teaching activity systems. The vice principal was present in the meeting and responded by saying that their policy concerning use and booking of the computer lab needed to be evaluated (see utterance 402, p. 163). Access to the computer lab at Austpark was ruled by a subgroup consisting of the principal, the IT leader at the school and a teacher. They used a registration form as an aid for teachers' bookings. After the school team meeting in December, the five teachers made bookings on this registration form for access to the computer lab after Christmas. Later, in their conference presentation in September 2006, Jakob and Frode referred to these early booking as an important effort. The effort was by Frode expressed as having the following effect: "We pushed ourselves to put emphasis on it" (see utterance 48 in Appendix 8vii, p. 346), where *it* relates to use of Cabri.

Thus, the issue of lack of good regular access to computer lab, which Gunnar emphasised as a critical problem in order to utilise computer software regularly in his teaching, were addressed in two main ways by the teachers. Partially in applying the school's booking system effectively by making early bookings and exploiting pressure on persons in command of making priorities to computer lab, and secondly by questioning the school's priority on general software training courses. Whether or not Gunnar in his meeting with the principal (see Section 5.4.2, p. 163), ahead of their school team meeting in December, pointed to the school's commitment to use computer software in mathematics as part of their participation in the ICTML project is not clear. It is neither decided whether or not the school will continue with general software training courses which monopolise the computer lab for long periods. In a e-mail response in June 2007 (see Event 42), Gunnar confirmed that access to computer labs still was a problem and indicated that the school still ran such training courses. The *divisions of labour* and the *rules* for use of computer software at the school had been raised as issues by the teachers indicating a tension which potentially could have provoked a contradiction for the school activity system. The rules in the school activity system were related to priority in their booking system and pedagogical priority of courses in software use which teachers did not experience as supporting their implementation of Cabri. The tension with division of labour related mainly to the teachers' lack of having influence in decision-making regarding use of the computer lab. Neither of these tensions seemed to have stimulated contradictions and expansive development within their school activity system. However, with their early bookings they were at least able to utilise the established rules and stress the division of labour through meetings with their principal.

d) Time on the geometry topic

Time as an issue was mentioned several times by the teachers, both in school team meetings at Austpark and in several workshops, when they discussed possible implementation of Cabri in their geometry teaching. Analytical findings in Section 5.4.2 indicate that extra time spent on Cabri was addressed by their choice of *priority* on the geometry topic. Jakob and Frode's expressed a wish to reserve extra time on geometry at the sacrifice of time to other topics. This decision made it possible to implement and use a new mediating artefact like Cabri in the geometry teaching at Grade 8. Thus, their priority on geometry made extra time available and supported their *expansive development* of a collective object on Grade 8: "Implementation and orchestration of Cabri-use in the geometry topic, building on use of compasses, with students' learning related to requirements in the Curriculum".

Control of time was mentioned many times when the teachers talked about their use of Cabri (see Section 6.1). In Chapter 7, I present conclusions concerning teachers' considerations of time when implementing computer software or other "new" tools in mathematics teaching.

e) Lack of testing outcome of Cabri teaching

This issue relates to the traditional way of testing the outcome of mathematics teaching through tests. Neither tests at the school during the year, their year examination nor the national examination at Grade 10 included use of Cabri or other kinds of DGS at the time when the teachers' started to consider implementation of Cabri. The importance of the issue was evident when Frode claimed that if they did not manage to design year examination with Cabri there would be no point in using Cabri (see utterance 228, p. 167). He continued by emphasising that the "year examination must reflect the teaching" (utterance 231). What Frode did was to argue by what I have denoted as an *unwritten rule* in the *community* of their school- and teaching activity systems: The *outcome* must be tested and reflect their teaching. Thus, to spend time on students' use of a mediating artefact in teaching if students' outcome from its use was not tested would be to raise a tension which could not energise an expansion for Frode's teaching activity system because of this unwritten rule. To apply the *same test* in all classes at a grade was also part of the *rules* at Austpark to which Frode was committed.

Harald at Grade 9 did not seem to be so committed to these two rules. In the school team meeting in December 2005, Harald referred to a limited value of using Cabri when neither the national examination at Grade 10 nor he had the possibility to include Cabri in tests at Grade 9. Despite this Harald did implement Cabri and he used Cabri in his class at Grade 9 during the winter 2006.

The issue concerning use of Cabri in tests, raised in the meeting in December by Jakob, was solved at their school level by Jakob and Frode's design of two tests at Grade 8 and through an organisational plan for carrying out the test within their computer lab environment. The issue generated a tension in the school activity system at Grade 8 stimulating an expansion made possible by managing to have Cabri use in all the classes at Grade 8. Frode's ultimatum concerning the necessity of designing tests with Cabri could be one reason why the tension energised this expansion at Grade 8. The design and use of tests supported the desired outcomes in the school activity system at Grade 8 where the importance of testing the outcome of students' actions with Cabri was crucial. I also see their efforts to design and use tests as aids when arguing for implementation of Cabri for their students, their colleague at Grade 8 and to students' parents or guardians. Thus, at Grade 8 the issue led to a contradiction energising an expansive development while the same did not occur on Grade 9 (and 10). A *reason* for the *different* situation at

Grade 9 and 10 was that all the mathematics teachers at Grade 8 implemented Cabri in their teaching while the same did not occur at Grades 9 or 10.

However, the issue regarding lack of use of Cabri in the national examination test at Grade 10 remained an unsolved *tension*. The teachers had to argue for use of a mediating artefact where motives in the curriculum gave no explicit support for use of Cabri nor was the outcome tested in the national examination. Why spend time on something that is not "checked" in test and examination is a kind of question members in a community commonly ask. Such kinds of contrasts are challenging for teachers and were comment in Section 5.4.2 (see p. 165) with references to Hennessy et al. (2005) and Monaghan (2001). The examination-issue served as a tension for teachers' desired outcome within the school activity system at Grade 8 but perhaps even a stronger tension at Grade 9 and 10 since Grade 8 is farthest off the national examination which takes place at Grade 10.

In their conference presentation more than half a year after their Cabri-teaching came to an end, Frode referred to the issue related to lack of implementation of Cabri in the national year examination which had been bothering him and his colleagues. In this conference presentation, he referred to his and Jakob's 'arrangement' (see Section 6.1.2) with compasses and Cabri (see utterance 79, p. 154). I consider this arrangement as a way of handling the *tension* related to only testing outcome related to use of compasses in the national year examination.

f) Teachers' own competences in using Cabri

Finally I want to pay attention to teachers' competences in using Cabri at Austpark as an issue; a personal factor according to the suggested list by Crisan et al. (2007) referred to in the introduction to this section. When I considered *why* the teachers at Austpark implemented Cabri in Section 5.4.1, concerns about teachers' competences where included. As already emphasised (see Section 5.4.2, p. 157), the workshop session held by Otto on the 14th of December happened to be a session focusing on teachers' competences in using Cabri and not the kind of "start-plan" which Harald expressed in the e-mail sent on the 27th of October (see Section 5.2.3, p. 135). Instead of having a session emphasising development of *shared objects* for use of Cabri within the school activity system at Austpark, the session rather stimulated teachers' own development in utilising the mediating artefact Cabri.

Jakob's entry into the KUL team at Austpark was expressed as crucial for the implementation of Cabri at Austpark (see Section 5.4.1). In the end of Cabri-use interview in March 2006, Harald emphasised Jakob's confidence in use of Cabri as important (see utterances 55, p. 150). Jakob's confidence together with Otto's contributions and the ready made teaching package from Jakob's former colleague in the master programme at UiA, which as mentioned fitted well into the motives in the National Curriculum at Grade 8, were important in making implementation of Cabri a *minor* step for the two teachers at Grade 8. The tension experienced by the teachers at Grade 8 when introduced to a new mediating artefact, was resolved in an expansive development at their school activity system at Grade 8. At least for Frode, this expansion was energised by a wish to do something new in mathematics teaching, have collaboration with teachers at Grade 8 and teach all the students in a similar way. Thus, to develop *collective object* and *outcome* that supported his personal *goals* for *actions* in teaching.

In the end of Cabri-use interview, Frode also called attention to their efforts to reserve extra time for work with the geometry topic at the sacrifice for other topics in the Curriculum. Their efforts to reserve extra time could indicate a great wish to succeed with the implementation of Cabri, but also that they realised that using Cabri for the first time would demand extra time. They wanted to teach both Cabri and compasses, the software was new for them and they and their students needed time to develop competences in utilising the software in teaching and learning.

5.6.2 Trude's personal oriented reasons and issues

In Section 5.5.1 I presented analytical findings concerning Trude's reasons and issues for implementation of Cabri. A difference between Jakob and Frode, and Trude were the number of institutional issues considered by Jakob and Frode (numbered a)-e) in Section 5.6.1, p. 173). These issues were related to their school and nature of collaboration at the school. The final more personal related issue addressed by Jakob and Frode, *teachers' own competences in using Cabri* was in fact the main issue emphasised by Trude with the implication of *daring to use* Cabri in teaching. Like Jakob and Frode, Trude also expressed concern for the *time* issue by emphasising the need of reserving extra time. Finally, her experienced *external expectation* from didacticians as part of her participation in the projects apparently was a reason for her implementation and in fact also an issue for her throughout her participation in the developmental projects.

Time was considered as an issue by Trude already in ICTML Workshop 3, the first workshop in the ICTML project where teachers worked with Cabri. When the teachers in that workshop were asked to discuss the possibility to implement Cabri in their teaching, time was an overall issue in several of the comments from the teachers attending the workshop. The expression to "reserve time" was mentioned both by Markus and Trude from Fjellet. After emphasising the necessity of reserving time, Trude continued by claiming: "For me it is of necessity if not I will not manage it" (see utterance 226, p. 124). Like for the teachers at Austpark, her wish to reserve time was a way to make it possible to implement Cabri with its associated object for teaching within her teaching activity system at Fjellet. Her priority by reserving time made an expansive development possible in her teaching activity system.

Trude's main emphasis was on her own expressed *lack of competence in using Cabri* and computer software in general. In a discussion session after a working session with Cabri in ICTML Workshop 4, she described her experience from working with Cabri at the workshop by comparing herself with her students who struggle with mathematics. This workshop contribution came more than half a year *before* her Cabri-teaching started. In LCM Workshop 10, five days *after* her first lesson with Cabri, she also commented how she had described her lack of skills in Cabri for her students. For Trude, the main issue seems to have been to *master* the mediating artefact itself and to *dare* to implement and use Cabri in teaching.

During ICTML Workshop 7, one week after LCM Workshop 10, Trude with great enthusiasm reported from her implementation resulting in initial use of Cabri in teaching. She referred to how she finally said to herself: "… then I thought, dammit, I just have to do it!" (see utterance 176, p. 138). This utterance could indicate that she experienced a pressure based on statements in the curriculum emphasising use of computer software in mathematics teaching. In Sections 5.2 and 5.3 I also argued that findings indicate that the external support by didacticians in the developmental projects served as vital, provoking a tension but stimulating the expansive development in Trude's teaching activity system. To be brave enough to start using Cabri in her teaching and orchestrate the teaching served as a tension but she succeeded and had an expansive development. For Trude, implementation of Cabri building on use of compasses became important for her object and closely related was the main part of her desired outcome: "Daring to use and make priority on Cabri and inquiry to fulfil expectations" (see Figure 5.3, p. 187).

As mentioned, only two of the six listed issues illuminated for the teachers at Austpark seemed to have been important for Trude's implementation of Cabri. One explanation for this difference could be her working conditions which differed from Frode's and Jakob's. At Fjellet they only had one class at each grade and therefore Trude had not the same need for coordination of her mathematics teaching and tests. In addition, she was the only teacher at the school implementing Cabri during the winter 2006 although Markus implemented Cabri later in the spring. However, when Markus started his use of Cabri in teaching Trude had a break from teaching for the rest of the school year so they had no coordination of their teaching. Since Trude implemented Cabri at Fjellet on her own during the winter 2006, this meant that she lacked the stimuli which the teachers at Austpark appreciated as important: To work collaboratively with the other mathematics teachers at the school. So for Trude, the stimuli from workshop sessions where she met other teachers that had implemented Cabri may have served as more important than for Frode and Jakob, and could be an explanation for her enthusiastic feedback during the workshops, like in ICTML Workshop 7 in January 2006. Another reason for her lack of emphasising other issues could be that her personal goal, to *dare* using Cabri, overshadowed other issues which she consequently did not consider and address. The latter will be emphasised in the analysis of her orchestration of Cabri-use in teaching (see Chapter 6).

5.6.3 Elements constituting teachers' motives and goals

In this final section I analyse *elements* constituting *teachers' motives* in the form of collective objects within their teaching activity system. The object was about implementation and orchestration of Cabri-use in teaching with students' learning of geometry related to aims in the National Curriculum (see Section 3.1.2, p. 62 and Figures 5.2 and 5.3). I also indicate with what goals teachers' addressed the motives in their teaching activity systems. In Table 3.1, I gave the following example to distinguish between goals and motives (see Section 3.1.2, p. 62):

> … the objects are about teachers' implementation, orchestration of Cabri-use in teaching with students' learning of geometry related to requirements in the National Curriculum in Norway. Accompanying the use of Cabri, teachers usually have some specific goals related to what they want their students to achieve when using Cabri in their work with geometry.

I study the teachers as the formal leader in their teaching activity system influenced by other teachers', school leaders' and didacticians' suggested proposed actions for teaching both in the school activity system and the KUL activity system. Consequently, teachers' motives were influenced by the *external support* analysed in previous sections which is evident from findings in Section 5.3.

In the analysis in this section (5.6.3) I utilise 'intersecting activity systems' (see Section 3.1.6). Figure 5.1 is a triangular model utilised to describe how *didacticians,* within the *KUL activity system,* through repeated *support* offered *expectations* and *proposed action* for the *school activity system* as well as each teacher's *teaching activity system.* The support was guided by a supposed *collective object*, in this study implementation of Cabri in geometry teaching. Each of the triangular models (see Figures 5.1, 5.2 and 5.3) illustrates *two intersecting activity systems*. Each of the figures should be interpreted as an activity system provoking issues and potential tensions and expansions for another activity system. The role of these representations was discussed in Section 3.1.6 and illustrated in Figure 3.6 (see p. 71).

In Figure 5.1 (see p. 185), the *red text* placed *above* each seven elements (Subject, Rules etc) in the activity system refer to the KUL activity system, while the *blue text* placed *below* points to how didacticians propose actions for the teaching activity system and indirectly the school activity systems based on aims in the LCM and ICTML projects. The text in *bold* indicates issues which potentially generated *tensions*, *contradictions* and *expansions* for the activity system. The figures are used to present schematic representations of the activity theory analyses in this chapter presenting links and issues.

For didacticians in the KUL activity system, teachers' development of their own *goals* for teaching with computer software was a desired outcome. In activity theory notions, *goals* are personal and conscious to which actions are directed. Hence I suggest that the desired outcome rather could be rephrased as: Teachers developing their own *objects* for teaching with computer software where objects related to motives and addressed in actions energised by teachers' goals.

In Figure 5.2 (see p. 186), I present a triangular model of the *school activity system* at *Austpark*, particularly emphasising the school activity system at *Grade 8*. The text in *red* placed *above* each seven elements in the activity system point to the school activity system at Austpark, while the *blue* text placed *below* point to how the teachers at Grade 8 worked to implement Cabri within their teaching activity systems in classrooms and computer labs. As for the previous figure, the text in *bold* indicates *issues* which when coped with potentially contributed to *expansions*.

Trude worked on her own with implementation and use of Cabri at Fjellet. Her desired outcome reflects her main *goal* energising her *actions* which seems to be to *dare* using Cabri despite her expressed limited skills in using computer software in teaching (see Chapter 6 for further analysis of her goals). In Figure 5.3 (see p. 187), I present a triangular model of the school activity system at Fjellet intersecting with *Trude's teaching activity system* at Grade 8. I argue that for Trude, the level of school activity system was not so visible. A big difference between Austpark and Fjellet was that Fjellet only had one class at each grade and at that time Trude was the only teacher at the school implementing Cabri in her teaching. Consequently, the tensions between goals for teaching with Cabri in the school activity system and Trude's teaching activity system were less visible. In Figure 5.3, the text in *red* placed *above* each seven elements in the activity system refer to the school activity system at Fjellet, while the *blue* text placed *below* refer to how Trude worked with her personal *goal* to implement Cabri as an desired outcome within her teaching activity system. As for the previous figures, the text in *bold* indicates *issues* which potentially generated *expansive development*.

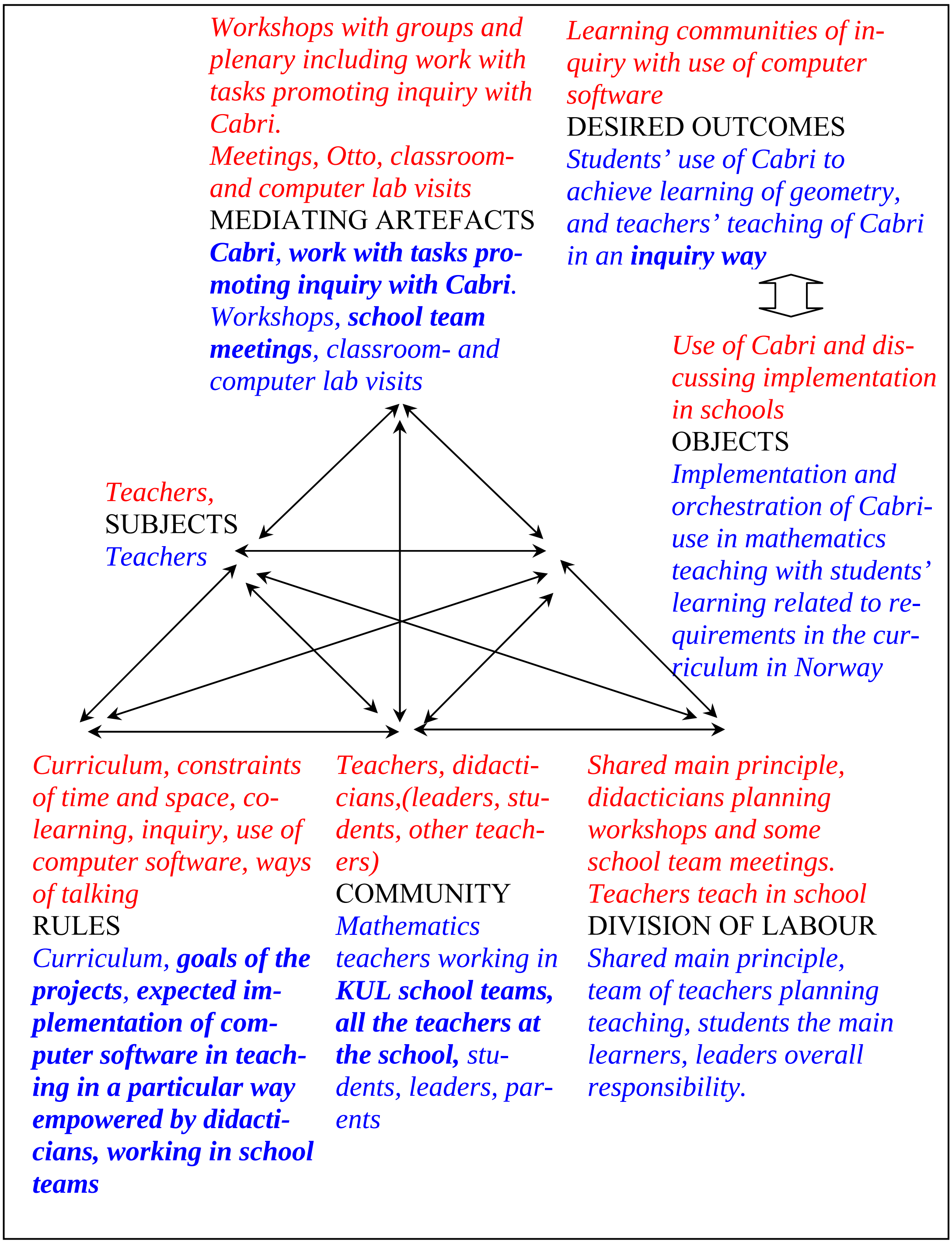


Figure 5.1: The KUL activity system proposed implementation of Cabri in each teacher's teaching activity system

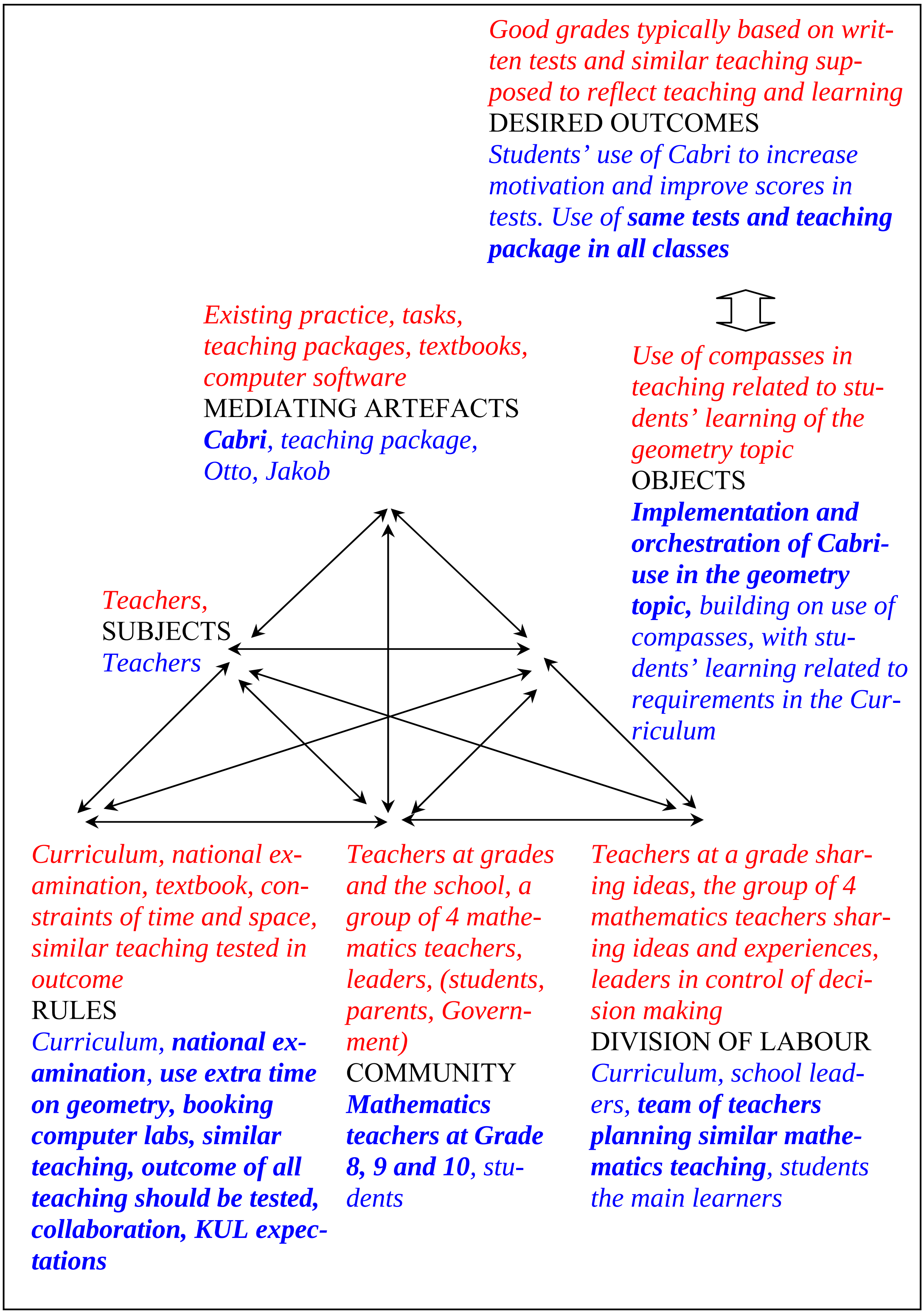


Figure 5.2: The school activity system's proposed implementation of Cabri in the teaching activity systems at Austpark

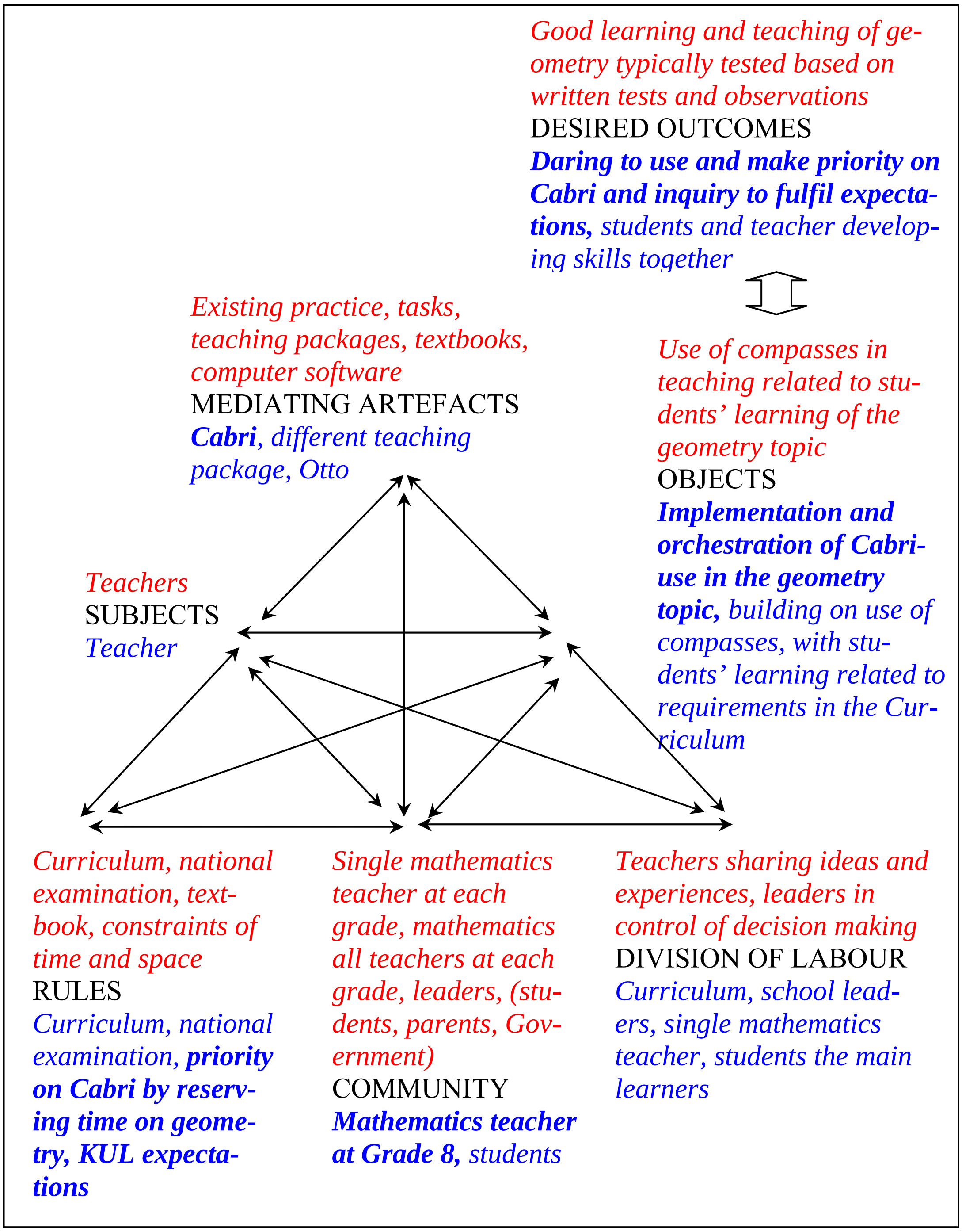


Figure 5.3: The school activity system's proposed implementation of Cabri in Trude's teaching activity system at Fjellet.

In all the three representations, I have used the term *desired outcomes* and I have included an arrow between objects and outcomes which is two-edged and not one-edged as commented in Figure 3.5. This has been done since the analytical findings in this chapter indicate that teachers' desired outcomes influenced on the objects and other elements in the activity systems during their implementation process. Later I indicate to which extent these desired outcomes were achieved since outcomes cannot be made but happen.

5.6.4 Critical findings and considerations for Chapter 6

Analytical findings in this chapter indicate that the suggested *object* related to implementation of Cabri, offered and supported by didacticians in the KUL activity system, seemed to have been important to *initiate* implementation of Cabri for al the three teachers in the study. Already in ICTML Workshop 3 in January 2005, Aud asked the teachers about their readiness for using Cabri in their teaching (see Section 5.2.1, p. 124). In school team meetings more support was offered by didacticians. In a school team meeting at Austpark in October 2005, Jakob informed didacticians and the other teachers about his and Frode’s plan for use of Cabri in teaching after Christmas. In the next school team meeting in December, Harald and Gunnar also expressed readiness and the meeting included a discussion concerning collaborative implementation of Cabri. One week later, Otto held a workshop session emphasising teachers’ development of competences in using Cabri which Jakob in the LCM/ICTML focus group interview in March 2006 emphasised as an important outcome of the project. Also at Fjellet, school team meetings were held during autumn 2005 and included didacticians and Otto. Otto contributed also more directly in teaching at Fjellet by conducting lessons with spreadsheets where Trude, Markus and Ludvig observed their students during Otto’s teaching. Early in January 2006, Trude referred to Otto’s contributions as valuable and reported that she had started to use Cabri in her teaching and thus had an implementation of Cabri.

Comments in this chapter indicate that the teachers emphasised the support offered by didacticians at UiA as being helpful and important for their implementation of Cabri. Obviously the matter concerning what would have happened without this involvement from didacticians is a difficult and really impossible question to answer. And how “free“ were the teachers in sessions conducted by didacticians in the KUL activity system to really address the value of the contribution by the didacticians? I have already argued that the analytical findings indicate that teachers sometimes experienced didacticians’ *support* as offering expectations to utilise the support.

When I in this chapter have considered elements that constituted teachers’ objects for implementation of Cabri, teachers’ desired outcome and goals for implementation of Cabri related to these objects seemed limited influenced by didacticians in the KUL activity system, particularly at Austpark. The *six issues* considered in Section 5.6.1, based on analytical findings in Section 5.4, *mainly* referred to school *institutional* matters in Austpark’s school activity system although the support from didacticians, in particularly Otto, was considered to be important by the teachers. In the next chapter I analyse Jakob and Frode’s arrangement of Cabri-teaching which involved a choice of utilising a written teaching package, teaching compasses and Cabri co-coordinated close in time and how the teachers experienced their teaching with Cabri. One of the findings is that despite repeated *emphasis* on *inquiry* by didacticians, the teachers at Grade 8 on Austpark argued that their teaching had minimal *inquiry* elements and that it was a suitable choice. To work with computer software in an inquiry way as suggested by the didacticians, did not constitute a vital part of teachers' goals which energised their teaching and actions in the classrooms.

On the other hand, Trude's goals and desired outcome reveal that Trude seemed more *affected* by the didacticians in the KUL activity system. This finding is supported by analytical findings in Chapter 6 concerning her actions and operations when orchestrating Cabri-use in teaching. In the first section in this chapter, I pointed to how she experienced *expectations* from her participation in the ICTML project like when she expressed that she *had to* start using Cabri. Trude did not experience or address the same number of internal school issues related to use of Cabri as the teachers at Austpark. To start using Cabri was for Trude more *personally* to dare start using the software in teaching.

The activity theory analysis in this chapter has illuminated teachers' motives in the form of objects within their teaching activity systems. Findings indicate that these objects were shaped within their school activity system and KUL activity system. The issues and tensions both within the school activity system and each teacher's teaching activity system and the role of the KUL activity system have been analysed. In addition, addressed issues sometimes energised expansions between the KUL activity system and the school- and teaching activity systems have been addressed. The development of collective objects through expansions have been considered in relation to the different elements in an activity systems: subjects, mediating artefacts, rules, community and division of labour

Related to these objects, teachers used Cabri in classroom and computer labs where their actions were energised by what they wanted to achieve, their goals and desired outcome. In school team meetings and workshop sessions, teachers did express comments indicating their goals such as to do something "new" and students having an advantage of utilising compasses and Cabri co-ordinated. However, this chapter has contributed in only a limited way to illumination of teachers' goals for actions and operations in what I denote as their teaching activity system. In the theoretical framework in Chapter 3 I quoted Kaptelinin claiming: "Actions are realized through *operations* that are determined by the actual conditions of activity" (Kaptelinin, 1996, p. 108). In Chapter 6, I illuminate relationships between teachers' goals and action, operations and conditions, the second and third level offered by Leont'ev. This is done through analysis of teachers' orchestration of Cabri-use in teaching including concerns for what the teachers emphasised when they considered their teaching.

6 Teachers' orchestration of Cabri-use

In Chapter 5 I emphasised reasons and issues raised by Jakob, Frode and Trude when they considered *implementation* of Cabri in their teaching. In this chapter I present analytical findings from analysis of Jakob, Frode and Trude's orchestration of *Cabri-use* in their teaching. The distinction I make in this thesis between implementation and use was first presented in the introduction to Chapter 2 (see p. 27). This distinction was given further treatment in the introduction to Chapter 5 (see p. 119), where I argued that the analysis of teachers' orchestration of Cabri-use in teaching in this chapter would involve their arrangements for use of Cabri as well as their teaching.

In order to analyse the teachers' orchestrations of Cabri use in teaching, I have considered the following main questions where a) relates to the arrangements and b), c) and d) relate to their teaching:

a) Within what kinds of arrangements did the teachers use Cabri?
b) What kinds of elements in Cabri were in focus during the teaching?
c) What characterised teachers' orchestrations within their focuses and arrangements for use of Cabri?
d) What did the teachers comment on when they talked about their Cabri-teaching?

In Section 6.1 I analyse Jakob and Frode's orchestrations of Cabri and in Section 6.2 Trude's orchestrations of Cabri. These sections are composed of sub-sections where I present analytical findings to address each of these questions leading to an overall discussion of their orchestrations of Cabri at the end of Sections 6.1 and 6.2. Finally, in Section 6.3 I give a further analysis of teachers' orchestrations of Cabri and discuss differences between the three teachers' orchestrations utilising both of the theoretical perspectives in my framework. In the analysis of teachers' goals for use of Cabri in Section 6.3.2 I consider findings from both Chapter 5 and this chapter.

In Chapter 1, I raised the two research questions which I have repeated several times in the thesis:

1) *With what motives and goals do teachers at Grade 8 implement and orchestrate Cabri-use in mathematics teaching?*
2) *What characterises teachers' initial orchestrations of Cabri-use in mathematics teaching at Grade 8?*

The activity theory analysis in Chapter 5 had a main focus on teachers' motives constituting their objects for implementing Cabri within their teaching activity system. This chapter has a main focus on teachers' orchestrations of Cabri-use in teaching where I utilise the instrumental approach (see Section 3.2). I also consider how teachers' orchestrations were energised by what they wanted to achieve, their goals, for teaching with Cabri. Hence, analytical findings in this chapter are directly related to Research Question 2 and partly related to Research Question 1.

6.1 Jakob and Frode's orchestrations of Cabri-use

In this section I emphasise Jakob and Frode's orchestrations of their Cabri-teaching. 'Orchestration' as a term is also incorporated in what Trouche refers to as 'instrumental orchestration' which was outlined in Section 3.2 and will be utilised in the analysis in Section 6.3. Trouche's use of 'orchestration' is thus stricter than the use of the term 'orchestration' which I presented in Section 2.3.2 and use in this section and Section 6.2.

Together with orchestration I utilise an associated term 'teaching operations' in this chapter. I have earlier in the thesis given the following elaboration of 'teaching operation' for my study (see Section 2.3.2, p. 50):

> In my study with Cabri I am able to observe *teaching operations* and what teachers emphasise in their teaching through their instructions and questions, but also, indirectly, to observe choices made in their planning, such as use of textbooks and teaching packages, supporting the use of Cabri in teaching. Teachers' teaching operations relate to aids developed by the teachers to orchestrate students' learning.

Building in this quote, I argue that Jakob and Frode's arrangement for use of Cabri could be considered to be an included part of their orchestrations for teaching with Cabri. In Sections 6.1.1 and 6.1.2 I present analytical findings concerning two such arrangements which I denote as pillars for Jakob and Frode's orchestrations of Cabri in their teaching. Firstly, that they decided to use a pre-made *teaching package* in most of their Cabri lessons as already considered in Chapter 5. Secondly, that their approach to teaching was based on co-ordinated use of c*ompasses and Cabri,* almost in parallel. The latter also involved, importantly for the teachers, testing of the outcome of teaching with both tools by designing Cabri tests as well as tests which included use of compasses. Thus, the two pillars were:

- Use of a teaching package in Cabri-lessons.
- Co-ordinated use of Cabri and compasses.

In Section 6.1.3 I consider what the teachers seemed to have *wanted to achieve* with their orchestrations of students' use of Cabri. I do this by paying attention to the *main focus* of their orchestrations (see Question b) above). Two related elements are illuminated. Firstly, a focus on students' development *of successful techniques in Cabri* (commented in Section 3.2.3, p. 77) by the teachers repeatedly referred to as *accurate use of Cabri*. For example, users of Cabri cannot just aim at points; they have to move the mouse pointer close to an intersection point between a circle and another line if the new line is supposed to pass through the intersection point. Secondly, apparently building on successful techniques and used as a verification criterion, teachers' emphasised *affordances* in Cabri such as *measuring* lengths and angles, *calculations* and most of all the *dynamic dragging-function*. The teachers also had some focus on students' *utilisation of affordances* in Cabri such as examples where the teachers emphasised the dynamic dragging-function to check whether a construction had been done correctly. In Section 2.3.3 I considered the role of affordances and constraints in computer software, and in Section 3.2.3 I gave the following description and example of how I see techniques, affordances and constraints being related in my study: "Two *constraints* in Cabri that users have to deal with are the *menu system* and development of *techniques in* Cabri in order to be able to utilise affordances in Cabri" (see p. 78). Thus, the two main focuses which the findings in Section 6.1.3 reveal are:

- A focus on students' development of successful techniques in Cabri.
- A focus on affordances and students' utilisation of affordances in Cabri.

In Section 6.1.4, the *nature* of teachers' orchestrations of students' use of Cabri in teaching, either occurring in classrooms or a computer lab, is considered (see Question c) above). The section emphasises the role of teachers' *teaching operations* in their orchestration. The role of teaching operations was exemplified above with reference to elaboration of the term in Section 2.3.2. In Section 6.1.4 I make references to Section 6.1.3 in order to relate the nature of teachers' orchestrations to the focuses in their orchestrations. I also relate the nature of teachers' orchestrations to their 'teaching style' (see references to Kerr (1996) in Section 2.2.4, p. 41) and to the role of 'teachers' interventions' (see reference to Goos et al. (2003) in Section 2.3.2, p. 50). Hence, the analytical findings highlight:

- Teachers' style of teaching in Cabri-lessons.
- Teachers' teaching operations in Cabri-lessons.

Teachers' arrangement for use of Cabri, their focuses in teaching and the nature of their teaching give me a basis for interpreting what the teachers wanted to achieve with their Cabri-teaching. In Section 6.1.5, analysis of data from conversations, meetings and in workshop session with teachers, where they *commented* their teaching with Cabri, are also included to give a perspective on their teaching with Cabri. Below I list the three main areas of analytical findings presented in Section 6.1.5:

- How teaching with Cabri was experienced.
- The role of inquiry when teaching with Cabri.
- How the teachers experienced students' achievements with Cabri

and their own role as teacher.

In Section 6.1.6 I give a brief summery of findings of Jakob and Frode's orchestrations of Cabri use in teaching. Later, in Section 6.3, Jakob, Frode and Trude's orchestrations are discussed further and analysed utilising the theoretical framework in Chapter 3.

6.1.1 Use of a teaching package in Cabri lessons

During a school team meeting at Austpark, on the 26th of October 2005, Jakob mentioned, for the first time for the didacticians, his and Frode's plan for implementing Cabri starting in January 2006. In the school team meeting six weeks later, intended to discuss implementation of Cabri at Austpark, Jakob introduced his and Frode's plan for using the *teaching package* designed by Bueie (see Section 5.4.1, p. 150) in their teaching with Cabri. I have already referred to the two mentioned meetings several times in Chapter 5 when I considered teachers' implementation of Cabri at Austpark.

The teaching package was indeed used in most of Jakob and Frode's lessons and often referred to when the teachers talked about their use of Cabri. In this section (6.1.1) I give a brief presentation of the teaching package, how the content relates to statements in the National Curriculum L97[26] in Norway and I suggest reasons for why Jakob and Frode wanted to use this package. Data from a total of six events are considered. An overview of these events is presented below in Table 6.1, where the numbers refer to the total list of events in the case study provided in the overview in Appendix 1.

Table 6.1: List of events considered in the subsections to this section (6.1.1)

Event	Date	Type of sessions
6	26.10.2005	School team meeting at Austpark
16	11.01.2006	LCM Workshop 10 at UiA
30	22.02.2006	LCM Workshop 11 at UiA
31	09.03.2006	End of Cabri-use interview at Austpark
38	05.09.2006	Austpark's KUL conference presentation at UiA
44	22.01.2008	End of ICTML project interview in January 2008

Similar as in the earlier presentation of transcripts in the thesis, I refer to the chronological sorted events, episodes and utterances listed in Appendix 7. Some of the episodes are attached in Appendix 8 with roman numerals marked chronological according to where it is quoted in the thesis. This is later illustrated (see p. 135) with Appendix 8i, p. 344, and the next one being Appendix 8ii, p. 344.

The structure and content of the worksheets in the teaching package

The teaching package consisted of seven worksheets. Each of the work-

[26] The abbreviation L97 was introduced in Table 2.1 on page 28

sheets contained goals for students' work with Cabri, and consisted of a mix of written instructions, supported with illustrations from the menu in Cabri, and tasks. All of the worksheets had a size of two pages whose extent, according to Jakob, were supposed to match well with a 45 minutes Cabri lesson.

As an example, I now briefly describe the content of one of the worksheets, Worksheet 3, to indicate its structure. A copy and a translation of Worksheet 3 are attached as Appendix 2a) and 2b). Worksheet 3 was used by both Frode and Jakob in their Cabri teaching in January 2006. In January the following year (2007), Jakob used the same worksheet (see Event 40 in Appendix 1) although he had transferred to GeoGebra instead of Cabri. In Worksheet 3, the main emphasis is on making points, segments, circles, 60° and 90°constructions, measuring lengths and angles, utilising the dynamic dragging-function and writing text in Cabri. Points d) and f) in Task 1 and Task 4 attempt to stimulate students' consciousness of their reasoning process by asking them to make written instructions in Cabri of what they observe and why. A similar emphasis is visible in the other worksheets in the teaching package, such as in Task 4 on Worksheet 2 where the students, assisted by the dynamic dragging-function, are asked to consider the size of the sum of angles in a triangle.

In all of the worksheets in the teaching package, the author uses *bold font* when referring to menu options in Cabri which students have not been introduced to in earlier worksheets. For example, when presenting how to write a comment in Cabri the author refers to the menu option **Text**. Bold text is also used in some other occasions such as in naming the tasks, in the heading of the worksheets and particularly in Worksheet 3 when presenting the name of the two types of triangles.

Reasons why Jakob and Frode wanted to use the teaching package.

In Chapter 2 I quoted Laborde emphasising how challenging teachers experience design of tasks to be utilised with computer software exemplified with Cabri. Both Laborde (2001) and Monaghan (2004) found that most teachers used and designed worksheets characterised as having elements of control or guidance which for these teachers usually were in accordance with their use of tasks from textbooks in non-technology lessons. Thus, Jakob and Frode's choice to use a ready made teaching package with worksheets, supposed to guide and support the teaching and students' work with Cabri, is not so surprising (see their *fourth* reason considered on page 198).

None of the didacticians in the ICTML project knew the teaching package by Bueie ahead of the project. In the ICTML project, another teaching package in Cabri consisting of worksheets had been demonstrated in one workshop. This teaching package was designed by Otto. In an end of ICTML project interview in January 2008 (see Event 44), the project leader in the ICTML project, Aud, considered why the teachers at Austpark chose the Bueie package and not the one by Otto. Aud argued that the relation between Jakob and Bueie could explain their choice. She also expressed some uncertainty about whether all the teachers knew that the teaching package designed by Otto was available on web, and that overall teachers' bustle could explain their choice.

Below I consider teachers' own comments about the background for choosing the teaching package. In the end of Cabri-use interview at Austpark in March 2006 (see Event 31 in Appendix 1), occurring some weeks after their teaching with Cabri, Jakob said that he thought the teaching package designed by Bueie looked *appropriate* to use (see Appendix 8viii, p. 346). What did he mean with this comment? In sessions ahead of, during and after their teaching with Cabri, Jakob and Frode have presented what I interpret as four main reasons why they decided to use the teaching package.

A *first* reason, mentioned several times, was the teaching package's potential to *support requirements in the Curriculum* in the geometry topic at Grade 8. Soon after Jakob's "appropriate" comment in the considered meeting above, Jakob gave Curriculum-support as a reason for their use of the package:

Ut	Who	What is said (translation)	What is said (original)
175	Jakob	… It was, yes, I thought he had managed to cover most of the syllabus in the textbook We lacked a bit on symmetry? [But then]	… Det var, ja, jeg syntes han favnet egentlig det pensumet som, står i boka stort sett. Vi manglet vel litt på symmetri? [Men så hadde vel]
176	Frode	[Mm]	[Mm]
177	Jakob	Otto had some	Han Otto noe da
178	Ingvald	Yes, you have been working with symmetry as well?	Ja har dere gjort har du jobbet noe med symmetri også?
179	Jakob	Yes I had, I think I used a worksheet with [such]	Ja jeg hadde, jeg var vel innom et ark med [sånn]
180	Ingvald	Yes	Ja
181	Jakob	symmetry, which Otto has designed.	symmetri, som han Otto har utviklet.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 10

By using the worksheets in the teaching package, together with one worksheet from the teaching package designed by Otto, he argued that requirements in the geometry topics in the Curriculum at Grade 8 would be well covered. In LCM Workshop 10 in January, which occurred in the early phase of their teaching with Cabri, Jakob had very similar comments emphasising that "he has included the curriculum at Grade 8 in his worksheets" (see Appendix 8ix, p. 347) mentioning symmetry as the only topic lacking in the Bueie package. By the comment "included the curriculum at Grade 8" Jakob probably referred to the content of their textbook and plane geometry. The curriculum presents six listed statements (see Appendix 3) in geometry at Grade 8 (Hagness & Veiteberg, 1999, p. 179-180; KUF, 1997, p. 167). Only the second, fourth and partly the sixth relate to plane geometry and Cabri where the latter statement also involves work with volume. Based on a careful look at the seven worksheets in the teaching package, I argue that the package does address the content of the second and fourth point. Since symmetry is not mentioned in any of the remaining points in the curriculum, Jakob's argument that they needed a worksheet with symmetry to cover the geometry curriculum seems strange but could indicate that their textbook treated symmetry.

A *second* reason for their decision was that the teaching package, as a pre-made material for teaching geometry at Grade 8, was *ready for use* in teaching. In the school team meeting at Austpark on the 7th of December, ahead of their teaching with Cabri, Frode said: "I think we potentially can apply the teaching package directly in teaching at the grade" (see utterance 149 in Appendix 8v). This comment indicates that the teachers appreciated the ready-made package and believed it could be used by students at Grade 8 without any further adjustments. The fact that it was produced by a respected colleague could be seen to support their faith in the package, although neither Jakob nor Frode explicitly expressed Jakob's relation to Bueie as an argument. The comment by Frode could also indicate that he interpreted the worksheets in the package to support a desirable pattern of work at the computer lab both for students and teachers. Later, I present this as the fourth reason for Jakob and Frode's use of the package.

A *third* reason concerns the package's particular appropriateness in an *early phase* with Cabri. In the same December meeting, referred to in the previous paragraph, the conversation continued when Frode argued that the teaching package would be good "in order to come to know the tool and all the terms it offers". One month later, when he had used Cabri only once in each of his classes, Frode in a response to Trude in LCM Workshop 10 , argued for his and Jakob's decision to use ready-made worksheets and "proceed tentatively together with the students" since all of them were newcomers with Cabri (see Appendix 8x, p. 347). In the above mentioned Episode 10 (see p. 196), from the end of Cabri-use interview in March, occurring some weeks *after* their teaching with Cabri, Jakob also commented that the package was good to use in an early phase with Cabri. He argued that his students were dependent on having proper instructions, and substantiated his argument by referring to poor performance by his students in previous work with investigative tasks organised as group work. Later, in their conference presentation half a year after their teaching period with Cabri, Jakob emphasised that the teaching package relieved the pressure from teachers being inexperienced with Cabri (see Appendix 8xi, p. 347). Jakob particularly argued that the teaching package gave security for teachers at their school who did not participate in the LCM and/or the ICTML project and thus, according to Jakob, lacked the same experience with Cabri as the teachers in the projects.

Jakob and Frode's comments in the previous paragraph in fact refer to a *fourth* reason for their use of the teaching package. This reason points to qualities in the package to *support well a desirable pattern of work* at the computer lab, both for students and teachers. Already in LCM Workshop 10 in January 2006 (see Appendix 8xii, p. 348), Jakob argued that the worksheets in the package had potential to be "self-going" in teaching. He argued that the students' could work well guided by the instructions in the worksheets while the teacher could walk around and "assist those who need it". When he described this *self-going* quality of the worksheets, Jakob introduced the expression *step by step nature* of the worksheets while in other sessions the expression *self-explanatory* teaching package was used. In a workshop session some weeks *after* their teaching period with Cabri (see Episode 3 below), Jakob and Frode also pointed to consequences if they had *not* used such a step by step teaching package with tasks in their teaching. In utterance 87 Jakob concluded that he meant use of the worksheets in the teaching package was the right thing to do "although they have not been such investigative tasks".

Ut	Who	What is said (translation)	What is said (original)
85	Jakob	The tasks they have worked with have been very concrete, and step by step	De oppgavene som de har jobbet med har vært veldig konkrete og sånn fra punkt til punkt
86	Frode	Mm.	Mm.
87	Jakob	But if they have worked with tasks which are not of this kind it has resulted in fifteen simultaneous hands up and as a single teacher I feel that I am not able to help them much. So the fact that we have had such precise tasks in advance, I get time to go round and assist them with the tasks, that I think has been correct to do although they have not been such investigative tasks.	Men hvis de har hatt noen oppgaver som ikke har vært sånn så har det vært femten hender i været samtidig og som enslig lærer så synes jeg at jeg får gjort veldig lite med å hjelpe dem. Så det at de har fått veldig sånnklare oppgaver på forhånd og at jeg får tid til å gå rundt og hjelpe dem med oppgavene, synes jeg har vært riktig selv om det ikke har vært sånn utforskende oppgaver.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 3

As emphasised in Chapter 5, investigative tasks and inquiry had been suggested when using of computer software in teaching, both in the developmental projects and in statements in the National Curriculum. Jakob's comment probably relates to this and the fact that his contribution came in a workshop session where inquiry in Cabri-teaching was considered. In other sessions, such as their conference presentation half a year after their teaching with Cabri, they also talked about a lack of using "*inquiry*-tasks" (see Appendix 8xiii, p. 348) in their work with Cabri. In Section 2.2.2 I denoted these as examples of *double innovation expectations* on the teachers which was discussed in the analysis in Chapter 5 and will be discussed in Chapter 7.

Jakob emphasised that in order to be able to *assist students who needed help* with Cabri, a structured step by step package, which guided students' work, was appropriate. Above I reported that Jakob referred to his experience that his students were *dependent on proper instructions* and that they expected him to help them a lot during work (see p. 197). The relief of having the self-going package available could be interpreted in respect to this experience of his class where pattern of work concerning teacher's and students' roles had developed. Furthermore, the package afforded the teachers the possibility to direct students' attention to any step in a given task in Cabri which students had not accomplished successfully.

So far in this chapter, I have outlined the content and form of a written teaching package decided to be used in the teaching with Cabri in Jakob and Frode's classes. Four main reasons for Jakob and Frode's decision to use the teaching package have been indicated:

- Covering requirements in the curriculum.
- Ready for use in teaching.
- Appropriate in an early phase with Cabri for both students and teachers.
- The step by step nature of the package supporting a desirable pattern of work at the computer lab.

Reasons for teachers' use of a teaching package are of interest in themselves, but when the teachers emphasised these reasons their arguments indicate what they regarded as important in initial mathematics teaching with Cabri. Use of the teaching package was obviously crucial in Jakob and Frode's teaching since it was used in most of their lessons. The role of the teaching package will also be discussed in the first part of Section 6.1.2.

6.1.2 Co-ordinated use of Cabri and compasses

Use of Cabri and compasses close in time was typical for both Frode and Jakob's arrangements for teaching. Such use of the tools is related to one of the analytical findings presented in Section 5.4.1 concerning Jakob and Frode's reasons for implementing Cabri. Reason 6 considers taking advantages of teaching compasses and Cabri in parallel (see p. 154). Jakob and Frode's students worked with the tools, often in consecutive lessons and with reference to Cabri in the lesson with compasses and vice versa. Thus, I denote teachers' use of the two tools as *co-ordinated teaching*. Such use of the tools was also mentioned as a deliberate choice by Frode half a year after their teaching period with Cabri (see Section 5.4.1, p. 154). Thus, in order to describe their teaching with Cabri, considerations of how Jakob and Frode orchestrated use of compasses in the classroom is important. I have included *both* lessons with use of compasses and use of Cabri when I consider the two teachers teaching in Sections 6.1.3 and 6.1.4.

In the subsections to this section (6.1.2), data from a total of eight events are considered. An overview of the eight events is presented below in Table 6.2, where, as for Table 6.1, the numbers refer to the total list of events in the case study provided in the overview in Appendix 1.

Table 6.2: List of events considered in the subsections to this section (6.1.2)

Event	Date	Type of sessions
14	10.01.2006	Classroom lesson with use of compasses (Jakob's class)
15	10.01.2006	Computer lab lesson with use of Cabri (Jakob's class)
16	11.01.2006	LCM Workshop 10 at UiA
18	18.01.2006	Classroom lesson with use of compasses (Frode's class)
19	18.01.2006	Computer lab lesson with use of Cabri (Frode's class)
27	07.02.2006	Conversation with Frode at Austpark
31	09.03.2006	End of Cabri-use interview at Austpark
38	05.09.2006	Austpark's KUL conference presentation at UiA

How the two tools were used co-ordinated

To substantiate how use of the two tools was co-ordinated close in time, I here consider two consecutive mathematics lessons on the 10th of January 2006 in Jakob's class. Jakob first had a lesson with use of compasses (see Event 14) and immediately afterwards a Cabri-lesson (see Event 15), his second ever Cabri-lesson. In these two lessons, the *same* geometrical properties of triangles and angles were addressed with the two tools. Jakob did not use Worksheet 2 in the teaching package in the Cabri-lesson, but his teaching in *both* of the lessons seemed to be influenced by the goals in Worksheet 2 which I indicate below. Worksheet 2 is available as Appendix 2b) and its listed goals are also presented in Figure 6.1:

Goals for the worksheet (translation)	Goals for the worksheet (original)
- learn to measure angles - learn to label points - learn what an acute angle, an obtuse	- lære å måle vinkler - lære å sette navn på punkt - lære hva en spiss vinkel, en stump

angle and a right angle are	vinkel og en rett vinkel er
- explore sum of angles in a triangle	- oppdage vinkel summen i en trekant

Figure 6.1: Goals for the work with Worksheet 2

In the first part of the Cabri-lesson, measuring angles, labelling points and exploring the sum of angles in a triangle with Cabri were emphasised. The same elements had been in focus in the lesson with compasses a few minutes earlier. Thus, both lessons addressed the two first goals of Worksheet 2. In the lesson with use of compasses, Jakob made a sketch of an acute angle on the blackboard naming the two sides of the angle and the vertex as illustrated below:

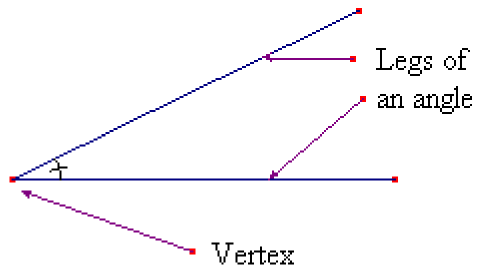
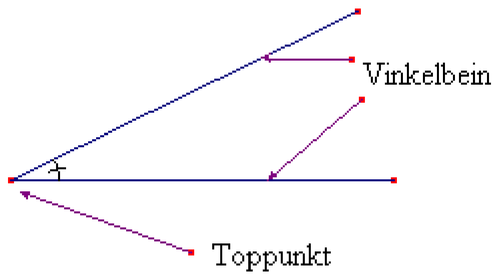
Copy of Jakob's sketch (translation)	**Copy of Jakob's sketch (original)**
	

Figure 6.2: Blackboard illustration from the classroom lesson, Event 13

Jakob began his lesson with compasses by asking his students what degree of an angle meant, particularly how big 90 and 360 degree angles are. Also, in plenary, he pointed to the difference between acute, obtuse and right angles, the third listed goals in Worksheet 2 (see Figure 6.1). This latter element was not repeated in the Cabri lesson. However, to explore sum of angles in a triangle, the fourth goal, was given attention in the Cabri-lesson. Thus, Jakob conducted "his own" lesson with Cabri following up on his lesson with compasses. In these two lessons the tasks addressed the four goals for Worksheet 2, a worksheet he did not use in his teaching. Consequently, despite not using this worksheet he seemed deliberately to address this worksheet in his teaching by utilising his co-ordination of compasses and Cabri.

Co-ordinated use of the two tools close in time was also evident when I observed Frode's Cabri-teaching. The two lessons in one of hs classes on the 18th of January, with respectively compasses (see Event 18) and Cabri (see Event 19), exemplifies this co-ordination. In the introduction to the lesson with compasses, Frode started off by emphasising that the students were supposed to work with the *same* four things; first using compasses and afterwards Cabri at the computer lab (see Appendix 8xiv, p. 348). The four things which he referred to were three kinds of constructions of perpendiculars and bisection of angles.

Thus, both Jakob and Frode utilised combined use of the tools as means in the teaching. In lessons with compasses, they explicitly referred to their students experience from work with Cabri and vice versa, and as mentioned both addressed similar geometrical constructions with the two tools.

The role of tests

During their conference presentation in September 2006 (see Event 38), eight months after their teaching with Cabri, Jakob and Frode referred to how the use of Cabri also had influenced on students' achievements with compasses in *tests*. As mentioned in Chapter 5 (see p. 167), few days after their teaching with Cabri came to an end Jakob and Frode designed and used a Cabri-test (see Appendix 5c) for all the students at Grade 8. In the end of year examination at Grade 8 in May, tasks to be approached with Cabri as well as use of compasses were included.

Already in Episode 13 from LCM Workshop 10, early in January 2006, Frode argued that his and Jakob's use of Cabri had to be accompanied by tests testing what had been emphasised in teaching (see Section 5.4.2, p. 167). They argued that tests in mathematics needed to reflect the teaching and consequently crucial for their use of Cabri. The test in January consisted of four tasks, where Tasks 1, 2 and 3 emphasised respectively construction of perpendiculars through a point on a line, from a line down to a point and the perpendicular bisector. In the final task, Task 4, students were supposed to construct both a 60 degree and 30 degree angle as part of the construction of a triangle. It is evident from my observation of their teaching with compasses and Cabri that the test did reflect elements emphasised in their teaching and in the teaching package; particularly Worksheets 2 and 3 (see Appendix 2). The role of the tests will be discussed further in Sections 6.1.3, 6.1.4 and 6.1.5 when I consider teachers' review of the test in January and how the two teachers experienced students' achievements in Cabri.

Use of Cabri influencing on students' use of compasses

Jakob and Frode also argued that use of Cabri influenced more directly students' ways of using compasses. In their conference presentation, Jakob referred to such experience from observing students' work with compasses after working with Cabri. He observed that the students were using compasses to construct in a *Cabri way*:

Ut	Who	What is said (translation)	What is said (original)
79	Frode	We chose to run quite in parallel. We worked with exactly the same in the classroom (*he seems to refer to use of Cabri at the computer lab*) and on the blackboard with compasses. Thus we wanted it to look similar with Cabri and on the blackboard.	Vi valgte å kjøre sånn parallelt løp. Vi jobbet med akkurat det samme i klasserommet (*her virker det som han mener datalab og bruk av Cabri*), og på tavla med passer og linjal. Så det var egentlig tanken at det skulle se likt ut i Cabri som på tavla.

80	Jakob	I started teaching geometry at the computer lab with Cabri before I started with compasses and ruler. We experienced that they constructed in a Cabri way. They mainly used full circles. I do not know if we (*interrupted*)	Jeg startet geometriundervisningen med Cabri på datarommet før jeg begynte med passeren og linjalen. Det vi så var at de konstruerte på en Cabri-måte. De brukte mest hele sirkler. Jeg vet ikke om vi (*avbrutt*)
81	Frode	The compass gap, I think they (*interrupted)*?	Passeråpningen, var ikke det noe med at de (*avbrutt*)?
82	Jakob	Certainly, the compass gap. On the big ones, the radiuses are all the way to the biggest circle (*Points with the mouse pointer in the circles visible on the screen. He emphasises that the students drew circles as in Cabri*).	Jo, passeråpningen. På de store her går radius helt bort til den største sirkelen. (*Peker med musepekeren inne i sirklene på lerretet. Han understreker at elevene laget sirkler som i Cabri*).

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 8[27]

In utterance 81 Frode, supported by Jakob in utterance 82, exemplified "constructing in a Cabri way" by referring to students' construction of a 90 degree angle with compasses which appeared different from the typical construction with compasses without full circles. Consequently, when the students accomplished constructions with compasses "in a Cabri way", it indicated that use of Cabri had influenced students' ways of constructing with compasses. Similar comments about constructions made in a Cabri way by their students, were also expressed by Jakob and Frode six months earlier during the end of Cabri-use interview in March 2006 (see Event 31).

Teachers' comments on their co-ordinated use of Cabri and compasses
In the end of Cabri-use interview, Frode gave an overall comment to their use of Cabri and compasses. He argued that he was "quite satisfied with" their use of the two tools, but emphasised that *more time* beneficially could have been reserved to the topic:

Ut	Who	What is said (translation)	What is said (original)
531	Frode	We could have reserved even more time because we first could have done the part we have done here, which I regard as basic in relation to constructions both in Cabri and when using compasses and ruler. Because then we would have had time to go further with problem solving and	En kunne satt av enda bedre tid til det for hvis en har gjort den første biten her, som jeg egentlig synes er bra å ta sånn grunnleggende i forhold til konstruksjon både i Cabri og med bruk av passer og linjal. At en da hadde hatt tid til og så gå videre med litt mer problemløsning og
532	Frode	[utilise]	[bruke]
533	Some	[Mm]	[Mm]

[27] Utterance 79 has already been presented in Episode 7 on page 154 in Chapter 5

534	Frode	the tool to other things.	verktøyet til andre ting.
535	Some	Yes	Ja
536	Frode	But beyond that, what we did I am quite satisfied with	Men ellers akkurat de vi gjorde er jeg stort sett fornøyd med.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 14

In this episode Frode argues that an extension of time would have made it possible to do problem solving with the tools. Concerns about time were also brought up as an issue when the teachers considered implementation of Cabri (see Chapter 5) and the role of problem solving and Cabri is emphasised in Section 6.1.5.

So far in Section 6.1.2, I have presented data from within and up to more than half a year *after* their teaching with Cabri indicating that Jakob and Frode considered their co-ordinated use of compasses and Cabri as a *success*. However, in a conversation between myself and Frode immediately after a lesson with spreadsheets, only two weeks after ending their teaching period with Cabri and compasses, Frode expressed more critical comments relating to this approach (see Episode 1 below). In fact, in Utterance 3, he argued that he considered his and Jakob's use of Cabri and compasses as "*not* really very good" based on experience during teaching and from students' hand-ins on the Cabri test:

Ut	**Who**	**What is said (translation)**	**What is said (original)**
3	Frode	…it is starting to come in distance for us (*refers to his and Jakob's teaching with Cabri and compasses which they had ended approximately two weeks earlier*). But the way we have used Cabri, to introduce it together with compasses, I think we almost can conclude that it was not really very good (*laughs*). The tool Cabri disturbed them. Therefore, they had to construct although they used compasses with circles, because they had to be very precise in order to hit these points. That disturbed them on the test. Many of them made figures which look all right, but when I test them they are not. This is because of the software, not necessarily because they have been thinking wrongly.	…det på en måte kommer helt i bak i hukommelsen (*viser til bruken av Cabri og passer i undervisningen som de hadde avsluttet cirka to uker tidligere*). Men måten vi har brukt Cabri på, at vi skal innføre det sammen med passer, jeg tror kanskje vi nesten kan konkludere med at det ikke var veldig bra (*ler*). Redskapet Cabri ble forstyrrende for de. Derfor måtte de konstruere selv om de brukte passer med sirkler, for de måtte være pinlig nøyaktig for å treffe disse punktene. Det virket forstyrrende for de på prøven. Det er mange som har laget figurer som ser riktig ut men som når jeg tester de er feil. Det er fordi programmet er sånn, ikke nødvendigvis at de har tenkt feil.

Event 27, Feb 7th 2006, Austpark, Frode, Cabri, Conversation, Audio, Episode 1

In this episode, Frode argued that *Cabri disturbed* his students since they were not able to use the tool with its needed *accuracy*. It seems that Frode experienced the need for students to move the mouse pointer close to, for example, an intersection point, to ensure that a line or circle pass through the point, as an obstacle in Cabri and not a criterion for the construction. When I consider Jakob and Frode's teaching with Cabri in Sections 6.1.3 and 6.1.5, their emphasis on this accuracy-dimension with Cabri is evident and typically expressed as "accurate use" of Cabri.

Although, in the quoted conversation above, Frode gave some critical comments to what I have denoted as *co-ordinated use of Cabri and compasses*, this was the only time any of the two teachers gave critical comments on their use of Cabri and compasses. The main overall frustration with their use of Cabri, which also is evident in the episode above, was the students' inaccuracy with Cabri. On the whole, both the teachers and their students reported the use of both compasses and Cabri as being *successful*. The latter was substantiated by their references to findings in a survey they had designed and used early in February 2006, approximately two weeks after the teaching period with Cabri. The survey was based on a questionnaire (see Appendix 5b) where students were asked to comment on the teaching with compasses and Cabri in January. Overall, the teachers commented that their students had been liked to work with Cabri alongside use of compasses, and in the questionnaire a big majority replied both Cabri and compasses when asked about what they believed would be the best way of working with geometry at Grade 8. The other suggestions in the questionnaire, only compasses and only Cabri, received few replies. This finding was mentioned by Frode in the end of Cabri-use interview in March (see Appendix 8xv, p. 349).

In this section I have presented analytical findings indicating that Jakob and Frode's teaching with Cabri and compasses were co-ordinated. The teaching occurred almost at the same time, often in consecutive lessons and the teachers exploited the two tools together by referring to Cabri use in lessons with compasses and vice versa. The students in a questionnaire expressed satisfaction with this co-ordinated use of the two tools.

6.1.3 Emphasis on techniques and affordances

In this section and Section 6.1.4, I present analytical findings from Jakob and Frode's orchestrations of students' Cabri use, focusing on a total of eight lessons. An overview of the eight lessons is presented below in Table 6.3 with references to events in the case study (see Appendix 1):

Table 6.3: List of events considered in subsections to Sections 6.1.3 and 6.1.4

Event	Date	Teacher	Tool and theme	Extent
14	10.01.2006	Jakob	Compasses	45 minutes
15	10.01.2006	Jakob	Cabri: Drawing triangles, measuring laterals and angles and introducing the dynamic dragging-function. Use of Worksheet 3 in the teaching package	45 minutes
17	17.01.2006	Jakob	Cabri: Construction of 60º, 90º and angle bisectors. Use of Worksheet 3 in the teaching package	90 minutes
18	18.01.2006	Frode	Compasses: Construction of perpendiculars and bisection of angles	26 minutes
19	18.01.2006	Frode	Cabri: Construction of perpendiculars and bisection of angles	60 minutes
25	07.02.2006	Jakob	Review of Cabri test	45 minutes
28	15.02.2006	Frode	Review of Cabri test and work with spreadsheet	45 minutes
29	21.02.2006	Jakob	Spreadsheet: Design of a budget including calculation of balance	90 minutes

This list of events includes some of their first lessons with Cabri, their reviews of the first Cabri-test, lessons with use of compasses and a spreadsheet lesson. Inclusion of different kinds of teaching events has been done deliberately in order to approach a characterisation of teachers' orchestrations of Cabri-use in teaching.

A focus on students' development of successful techniques in Cabri

Teachers' focus on students' development of successful *techniques in Cabri,* by the teachers repeatedly referred to as *accurate use of Cabri*, was in the introduction to this chapter (see p. 192) presented as being one of two main emphases in Jakob and Frode's orchestration of Cabri-use. Below I first show how techniques were in focus in teachers' reviews of the Cabri-test and then how techniques were addressed in their teaching weeks earlier. In this way I illustrate continuity in teachers' emphasis in lessons, in the subsequent Cabri-test and their reviews of the test. The teachers wanted to test the outcome of what had been emphasised in their Cabri-teaching.

The first Cabri-test was accomplished on the 2nd of February 2006 (see Appendix 5c for a copy of the test). Jakob's review of the test in a lesson 5 days later (see Event 25) started with a 25 minutes plenary. During this plenary review, Jakob several times referred to techniques in Cabri by emphasising the importance of *accurate use of Cabri* arguing that many students had used Cabri inaccurately and thus unsuccessfully. This is evident in Episode 1 (see Appendix 8xvi, p. 349) from the review of Task 1 point b) in the test, which concerned construction of a bisector in a point *P* on a line *k*. In the episode, Jakob stressed *moving the mouse pointer* all the way over to the point on the first circle which the new circle had to intersect. He substantiated his argument by referring to a typical unsuccessful technique used by the students. ".. I can *not just aim* for the point…" A similar focus on techniques was evident in Frode's plenary review of the test (see Event 28). Later in this section, I present an episode from his review-session where he commented to his students saying "…you did not manage to hit the points accurately. You have *not hit* the line, circles accurately." (see utterance 27, p. 213).

As indicated, a similar focus on students' successful techniques was also evident in their lessons weeks ahead of the Cabri-test. In fact, I argue that teachers' emphasis on techniques in Cabri *also* was visible in their lessons with compasses which, as highlighted in Section 6.1.2, were co-ordinated with lessons using Cabri. More precisely, in lessons with compasses Jakob and Frode referred to compatible techniques with Cabri, such as in the episode below from a lesson with compasses where Frode considered construction of perpendicular from a point:

Ut	Who	What is said (translation)	What is said (original)
39	Frode	When we make a perpendicular we have to do something. Can anyone help me? Bent?	Når vi skal ha en normal må vi gjøre noe. Er det noen som kan hjelpe meg? Bent?
40	Bent	Put your compasses in the point	Du setter passeren i punktet.
41	Frode	[Yes]	[Ja]
42	Bent	making a stroke across the line	setter en sånn strek på linja
43	Frode	[Yes]	[Ja]
44	Bent	keeping the same length	Og så holder du samme lengde
45	Frode	Keeping the same compasses opening, yes. Good!	Holder samme passeråpning, ja. Bra!
46	Bent	And you make a mark on the other side	Og så merker du av på andre sida
47	Frode	[Yes]	[Ja]
48	Bent	Then you put the tip of the compasses in the intersection point	Så setter du passerspissen i skjæringspunktet
49	Frode	Mm	Mm.
50	Bent	And then keeping (*interrupted*)	Og så holder (*avbrytes*)
51	Frode	What I think now is important concerning Cabri. In Cabri it is important to drag the circle all over (*refers to the construction of perpendicular in Cabri where the diameter of the first circle becomes the radius for two new circles*) so it recognises the distance on the circle, the size of the circle and make an arch.	Det jeg har tenkt nå er viktig i forhold til Cabri. I Cabri er det litt viktig at vi lager denne sirkelen helt over der (*viser til hvordan normalen konstrueres ved å la to nye sirkler få diameteren i den første sirkelen som radius*) slik at den kjenner igjen disse avstandene på sirkelen, sirkelstørrelsen og slår en bue.

Event 18, Jan 18th 2006, Austpark, Frode, Compasses, Classroom, Audio, Episode 2

In this episode, Frode first focused on successful technique for the construction with compasses before, in utterance 51, he explicitly referred to Cabri and technique to apply when constructing with Cabri. He mentioned the importance of drawing *full circles* and techniques when drawing these. This construction was also accomplished in a plenary in the following Cabri lesson (see Event 19) and is considered in the episode below. The construction is illustrated in Figure 6.3 which for convenience is supported with names for the line, circles and points.

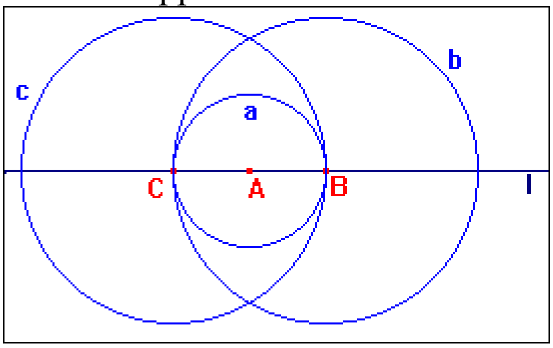


Figure 6.3: Illustration of the perpendicular-construction

In the episode, Frode stressed the importance of accurate use of Cabri, and *not* just "*aim at* and make the circles occasionally" as he phrased it. By accurately, Frode referred to a successful technique: the two new circles (circle *b* and *c*) needed to have their centres (respectively *B* and *C*) and circumferences through the intersection points between circle *a* and the line *l*. Frode also explicitly referred to what they did in the lesson with compasses. This similarity in content and teaching approach illustrates the co-ordination of the two tools.

Ut	**Who**	**What is said (translation)**	**What is said (original)**
18	Frode	How did we do it on the blackboard (*refers to the lesson ahead with compasses*)? Guro?	Hvordan var det vi gjorde det på tavla (*eferere til timen like før med passer*)? Guro?
19	Guro	We made a circle which was on both sides	Vi laget en sirkel som var på hver side
20	Frode	We made such marks on each side. Can you remember? Points on each side. The way we do it here is to make a circle. Click on circle (*refers to"Circle" on the menu bar in Cabri*). It is important that you hit the points you are basing the circle on. That you do not just aim at and make the circle occasionally. When you have clicked on the circle (*refers to "Circle" as a menu options*) you move down to the	Vi laget sånne på hver side. Husker dere det? Punkt på hver side. Måten vi gjør det på her er å lage en sirkel. Trykker på sirkel (*viser til valget "sirkel" i menylinja til Cabri*). Det er viktig at dere treffer de punktene som skal være utgangspunkt for sirkelen. Dere kan ikke bare blingse og lage sirkelen sånn tilfeldig. Når du har trykket på sirkelen (*viser til sirkel som et menyvalg*) går du ned til punktet

		point saying "This centre point". Then you click there and drag it out a bit. It is important that you do not move your pencil (*he refers to the mouse pointer*) up-wards because it is supposed to be down on the line, to have it on the line. Then I fix it there.	så står det "Dette er sentrum". Så trykker du der og drar litt utover. Så er det litt viktig at du ikke beveger blyanten (*viser til musepekeren*) din oppover for den skal ned på linja for å få den på denne linja. Så fester jeg den der.

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio, Episode 4

In this episode, Frode emphasised *how to move the mouser pointer* in Cabri with a well functioning technique and argued that the *appearing text*, "This centre point", was worth paying attention to when "fixing" the circumferences. Frode's use of the term 'fix', and on the coming pages Jakob's use of 'hook' and 'glue', to emphasise use of the mouse pointer to make sure for example a circumference passes through a point, is considered as a kind of *teaching operation* utilised by the two teachers (see Section 6.1.4, p. 226).

In the final part of utterance 20, Frode emphasised the importance of not moving the mouse pointer away from the line in order to ensure that the circle passes through the line. Since it is not necessary to keep the mouse pointer close to the line in this construction, this emphasis was unnecessary for a successful construction except that Cabri marked the point as an intersection point.

Like Frode, Jakob too had a focus on successful techniques in Cabri during his teaching. In his Cabri-lesson on the 17th of January (see Event 17), Jakob stressed techniques with Cabri when he gave a plenary pres-entation of the construction of a 60 degree angle emphasising accurate use of Cabri illustrated below in Episode 1. The quoted episode is from the final part of the construction where he explained how to draw the circumference of the second circle (see *b*) through the centre (see *A*) in the already made circle (see *a*). The construction is illustrated in Figure 6.4. The 60 degree angle can be made by drawing a line from A to one of the two intersection points between the circles. If we name the point C, $\angle BAC=60^{o}$:

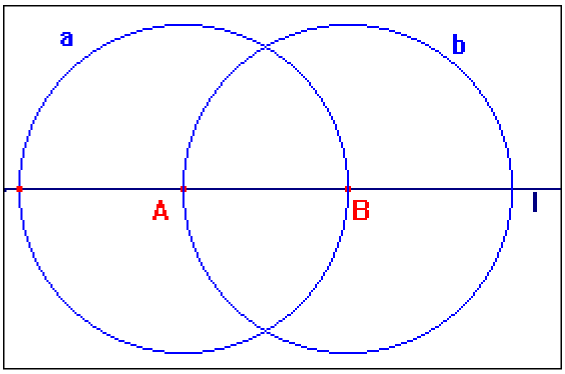


Figure 6.4: Illustration of the 60 degree construction

In utterance 83 Jakob made a note about being careful with the *mouse-pointer* and *move* the pointer in order to *hook* the circle on the point which in the illustration above is named *A*:

Ut	Who	What is said (translation)	What is said (original)
76	Jakob	This point on the circle (*refers to point B, see Figure 6.4*). And now I hook him (*use of "him" refers to Circle hooked to point A*). Then I choose the pointer again. What do you think will happen now? (*Jakob drags in Circle a; Circle B increases simultaneously*)	Dette punktet på sirkelen (*viser til punkt B, se Figure 6.4*). Og nå hekter jeg han fast (*bruk av han viser her til sirkel b som hektes fast i A*). Og så velger jeg pekeren igjen. Hva skjer nå tror dere? (*Jakob drar i sirkel a; sirkel b endres samtidig*)
77	Arve	They will be equal	De blir like store
78	Jakob	Yeahh!	Yeahh!
79	Several	Eahh (*applause*)	Eahh (*applaus*)
80	Jakob	Clever! Isn't it?	Fiffig! Ikke sant?
81	Arve	Certainly	Jo
82	Several	(*some noise*)	(*litt støy*)
83	Jakob	You have to be accurate. That you use the pointer to point where it (*refers to circle b*) is supposed to be suspended.	Vær litt nøye med det. At dere bruker den pekeren og peker hvor den (*referer til sirkel b*) skal ligge fast henne.

Event 17, Jan 17th 2006, Austpark, Jakob, Cabri, Computer lab, Video, Episode 1

Jakob's plenary with construction of 60 degree angle considered above occurred near the end of a lesson where his students had worked guided by Worksheet 3 in the teaching package (see Section 6.1.1). Worksheet 3 is available in Appendices 4c) and 4d). Task 2 in the worksheet treated construction of 60 degree angles, and Figure 6.5 below is a copy of this task. Why did the students have the observed problems in succeeding with the construction?

During students' work with point 2 and 3 in Task 2 I observed that several of them did *not move* the *mouse pointer* to ensure that the circles, used in the construction of 60 degree angles in Cabri, had the same radius. Thus, what Jakob did in his plenary was to raise his students' consciousness to their unsuccessful technique and in the presented episode above he basically accomplished the third listed point in the instruction:

Task 2 (translation)	**Task 2 (original)**
a) **Construct** a 60° angle.	a) **Konstruer** en 60° vinkel.
Construction of 60° angle 1. Draw a **line** and create a **point** A where you want the vertex. 2. Draw a **circle** with centre in A. Name the intersection point B between the circle and the line. 3. Draw a new **circle** with its centre in B	**Konstruksjon av 60° vinkel.** 1. Tegn en **linje** og avsett et **punkt** A, der du ønsker toppunktet. 2. Tegn en **sirkel** med sentrum i A. Kall skjæringspunktet mellom sirkelen og linjen for B. 3. Tegn en ny **sirkel** med sentrum i B

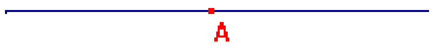
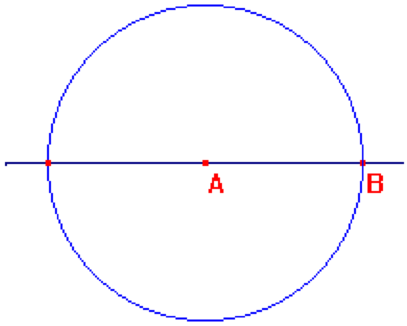
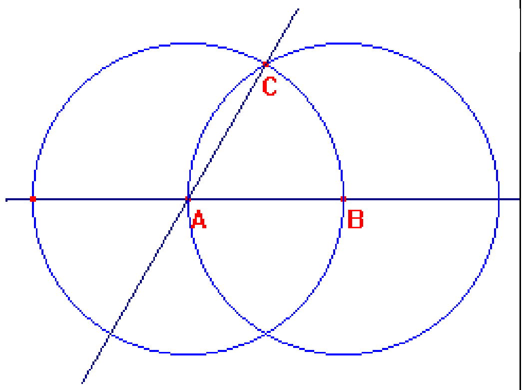
which passes through A. Name the intersection point C between the circles. Draw a line between A and C.	som går gjennom A. Kall skjæringspunktet mellom sirklene for C. Trekk opp en linje mellom A og C.
1.  2.  	3. 
b) Verify that the angle is 60° by measuring the angle. Repeat exercise a) until you are sure that you mange it..	b) Kontroller at vinkelen er 60° ved å måle vinkelen. Repeter oppgave a til du er sikker på at du kan det.

Figure 6.5: Task 2 on Worksheet 3

Summarised, both Jakob and Frode had a repeated focus on students' development of successful techniques with Cabri typically expressed as accurate use of Cabri. Importance of precise moves of the mouse pointer, as illustrated above, were often mentioned. I observed clearly an emphasis on techniques and minor emphasis on why the techniques worked geometrically in their Cabri-lessons. For example, in the Cabri-lesson considered above (Event 17) Jakob said nothing explicitly about *why* the 60 degree construction worked. However, when the same construction was included in their Cabri-test and considered in the review of Task 4 in the test (Task 4 and the three other tasks in the test were described in Section 6.1.2, p. 202). Jakob, to a greater extent, emphasised the why-dimension when arguing that the two circles had to be equally big (see Appendix 8xvii, p. 350). The observed emphasis on *techniques* in Cabri is similar to what has been argued by Monaghan (2004) who emphasises teachers' focus on students' learning to use the tool. Such use of the tool is according to Monaghan typical and natural in an early phase of work with a computer software tool in order to be sure technical problems do not obstruct students' utilisation of the tool.

A focus on affordances and students' utilisation of affordances in Cabri

The *second* main focus in teachers' orchestrations of students' Cabri-use was on *affordances* in Cabri and how to *utilise* some of these affordances. In Section 2.3.3 I considered how teachers could orchestrate by *constraining* students' work in order to handle affordances in the software. In this subsection I will argue that both use of the teaching package and teachers orchestrations contributed to structuring and constraining students' utilisation of some of the affordances in Cabri. On the coming pages I first consider teachers' focus on the *dynamic dragging-function* and later the *measure*- and *calculation* affordances which they often utilised to *verify techniques*. Thus, analytical findings in this subsection emphasise that *teachers' focus on techniques and affordances were related.*

Jakob introduced the dynamic dragging-function during his second lesson with Cabri (see Event 15). In that lesson, the students first drew triangles composed of line segments in Cabri. Jakob also demonstrated how to measure the laterals and angles in the triangle. Jakob's introduction of the measure-affordances is considered later in the section (see p. 215). He introduced the dynamic dragging-function (see Episode 3 below) with a particular focus on *how to use* this affordance in Cabri. In utterance 52 he presented how to use the mouse-pointer to *move* the measured corner emphasising the *changes* in the *size* of the measured angle. He challenged his students to *utilise* the dragging-function to *adjust* the measured angle to the size of 90 degree:

Ut	Who	What is said (translation)	What is said (original)
52	Jakob	Have you managed it? You will experience that you get different degree-measure. It depends on how you have drawn it (*refers to the triangle each student has made with segments*). If I move the mouse pointer all the way to the left you will be able to drag in a corner (*of the triangle*). Can you see that the angle changes?	Har dere fått det til? Nå kommer dere til å få masse forskjellige grader. Det kommer an på hvordan dere har tegnet det (*viser til trekantene som hver elev har laget ved hjelp av linjestykker*). Hvis jeg går på pekeren helt til venstre så kan dere dra i hjørnet (*til trekanten*). Ser dere at vinkelen forandres?
53	Stig	Yes, it does become 80, 90	Ja det blir jo 80, 90
54	Jakob	Shall we try to get 90?	Skal vi prøve å få han på 90?
55	Olaf	Yes	Ja
56	Jakob	Can we mange it? (*7 seconds pause*). It is hard to have exactly 90. Can you see the changes?	Klarer vi det? (*7 sekunder*) Det er vanskelig å få akkurat på 90. Ser dere at de forandrer seg?

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 3

Jakob and Frode's emphasis on *affordances* and *utilisation of affordances* went alongside the focus on *development of successful techniques* in Cabri. In the episode below from Frode's review of the Cabri test (see Event 28), *utilisation* of the *dynamic dragging-function* was expressed as a *check* as to whether a construction had been done successfully or not. If the angle was still 90 degree after dragging in one of the two sides of the angle, the construction had probably been done accurately with a successful technique. In fact, Frode expressed this dragging-check as his criterion for awarding students two or one point on this task which was Task 1 in the Cabri-test in February (see Appendix 5c):

Ut	Who	What is said (translation)	What is said (original)
25	Frode	… If your figure now is such a shape that if you pull in the line *k* and drag it and it is still connected and 90 degree all the way	… Hvis din figur nå er sånn at du kan ta tak i linja k der og vri på den sånn at det henger sammen at det er 90 grader hele veien.
26	Jens	[Yes, I can]	[Ja, det kan jeg]
27	Frode	Then you have scored two points (*on the test*). But if he changes (*use of "he" refers to the angle*) when you drag on him, not 90 degree all the way, then I only have awarded you 1 point since you in a way have managed to make the circles. If you think it looks all right, it could be that you did not manage to hit the points accurately. You have not hit the line, circles accurately. You have missed a bit, you know how to do it but have not been able to cope with the software Cabri accurately. You received 1 point instead of 2 points. Do you understand? That was Task 1 (*refers to Task 1 in the test*).	Da har du fått to poeng (*på testen*). Hvis han (*bruk av "han" henviser til vinkelen*) er sånn at når du tar tak i denne at vinkelen forandrer seg, ikke er nitti grader her hele veien, da har jeg gitt deg 1 poeng for at du har på en måte har klart å sette opp sirklene. Hvis det ser riktig ut så kan det være at du ikke har truffet punktene nøyaktig. Du har ikke truffet linja, sirklene nøyaktig. Du har bommet litt, du vet hvordan det skal gjøres men du har ikke klart å håndtere programmet Cabri ordentlig. Da har du fått 1 poeng i stedet for 2 poeng. Skjønner dere det? Det var oppgave 1 (*viser til oppgave 1 på testen*).

Event 28, Feb 15th 2006, Austpark, Frode, Cabri, Computer lab, Video, Episode 1

In his review of the three other tasks in the Cabri-test, Frode repeated the emphasis on the *dynamic dragging-function* as a *verifier* for techniques used when constructing geometrical objects such as in his review of the triangle construction in Task 4:

Ut	Who	What is said (translation)	What is said (original)
67	Frode	And finally you received 3 points if you managed to construct 30 degree in this way. And it has to work. And if he works you can drag in the line but still have a triangle which is connected.	Og til slutt fikk du 3 poeng for å klare å konstruere 30 grader her sånn. Og så må han fungere. Og hvis han fungerer så kan du ta tak i linja og dra sånn og så henger trekanten sammen.

Event 28, Feb 15th 2006, Austpark, Frode, Cabri, Computer lab, Video, Episode 2

Much of the same focus was evident in Jakob's review of the Cabri test. In the plenary review of Task 1, one of Jakob's students, Karl, accomplished the constructions in Cabri instructed by Jakob. In his instructions, Jakob challenged Karl to utilise the dynamic dragging-function as a *checker* (see Appendix 8xviii, p. 351). In the review of Task 4 in the test, dragging was very clearly expressed as a *check* for successful construction of a 60 degree angle in a point *A*:

Ut	Who	What is said (translation)	What is said (original)
134	Jakob	And then yes (*Karl drags in the line, the size of the angle remains 60 degree*) and then you can drag the line *o*, a bit up and down. The angle is still 60 degree! Okay, so far I have constructed correctly. This works!	Og så ja (*Karl drar i linja men størrelsen på vinkelen er fortsatt 60 grader*) og så kan du tak i selve linja *o*, og så dra den litte grann opp og ned. Så er det hele tiden seksti grader! Okay da så langt så har jeg konstruert riktig. Dette henger på greip!

Event 25, Feb 7th 2006, Austpark, Jakob, Cabri, Classroom, Video, Episode 4

In this episode, Jakob demonstrated use of the dragging-function almost as a *proof* for a successful construction when saying: "Okay, so far I have constructed correctly". Teachers' repeated emphasis of the dynamic dragging-function, particularly to verify a construction and to distinguish drawings and constructions, is similar to what Ruthven et al. (2005) reported in the paper quoted in Section 2.2.6 (see p. 45).

Apart from utilisation of the dynamic dragging-function, both Frode and Jakob also emphasised the *measure-affordances* and in hand *utilisation of* this affordance. The final part of Frode's plenary in one of his Cabri-lessons (see Event 19), included a brief contribution by Frode concerning how to draw up the perpendicular based on the construction of a 90 degree angle. The final step was a focus on how students could *measure* the size of *angles* in Cabri and in fact *verify* whether their 90 degree constructions were successful. In the Episode 5 below I refer to the labels included in the illustration of the construction in Figure 6.6:

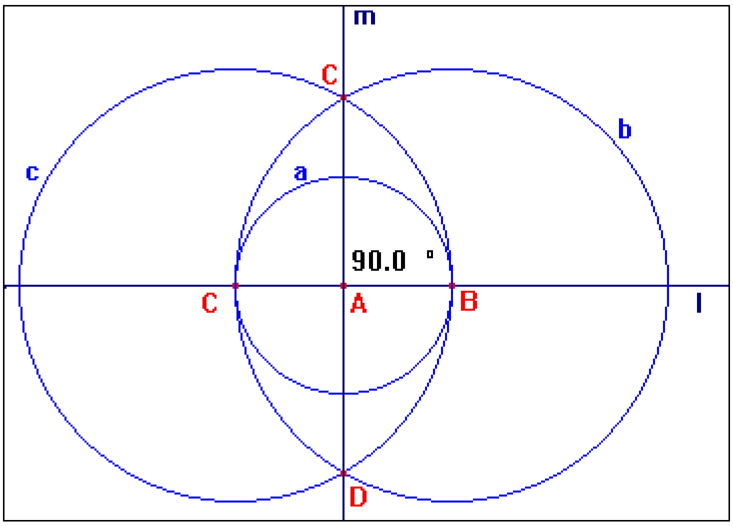


Figure 6.6: Illustration of the 90 degree construction

Ut	Who	What is said (translation)	What is said (original)
31	Frode	Then we draw the perpendicular (*which I have named m in Figure 6.6*). I take a line, look here, "Point at this intersection" (*refers to the message appearing in Cabri when the mouse pointer is close to the intersection point between the two circles, named C in Figure 6.6*). Then I can make a click. We cannot do it there (*refers to outside C*), then we have missed. We have to see "This intersection point" appearing. We can control it. We can choose "Angle", start with this point (*refers to the intersection point I have named C*), the vertex (*A*) and to this point (*refers to the intersection point named B*), like this. Juhuu! (*90 degree appears on the screen*). Those of you who achieve 90 degree have succeeded.	Så skal vi trekke normalen (*som jeg i Figure 6.6 har gitt navnet m*). Jeg tar ei linje, se nå, "Dette skjæringspunktet" (*viser til meldingen som kommer i Cabri når musepekeren nærmer seg det øvre skjæringspunktet mellom sirklene, kalt C i Figure 6.6*). Da kan jeg trykke. Vi kan ikke ta der (*viser til et sted et stykke bortenfor C og D*), da har vi bommet. Vi må få "Dette skjæringspunktet". Vi kan kontrollere det. Vi kan gå inn der velge "Vinkel", starte med dette punktet (*viser til skjæringspunktet jeg har kalt C*), toppunktet (*A*) og går ned til dette punktet (*skjæringspunktet som jeg har kalt B*), sånn. Juhuu! (*90 grader kommer fram på skjermen*). De som har fått den her på 90 grader har fått det til.
32	Several	(*Noise, the students work for a while until a pause before the second 45 minutes of the lesson*)	(*Støy, går over i arbeidsfase som varer fram til pausen før siste 45 minutt av dobbelttimen)*

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio, Episode 5

When I observed Frode's orchestrations of students' work in the rest of this lesson, he had a repeated focus on utilising the measure-affordance to verify whether the techniques used for the constructions were successful. Thus, there was a clear coherence between what Frode stressed in his plenary and when assisting students individually afterwards.

Jakob introduced the measure-affordance already in his second Cabri lesson where students first measured *lengths of laterals* in triangles and then *degree of angles*. In the episode below from Jakob's plenary in this second Cabri-lesson, he introduced the students to where the measure-affordance is located in the menu bar. In utterance 48 he presented his *suggested technique* for measuring degree of angles in a triangle based on three points. He created points on the two laterals connected to the corner to be measured, instead of using the three corners in accordance with standard notation for writing angles (such as ∠ABC). I denote this as *Jakob's special technique for measuring angles in a triangle*:

Ut	Who	What is said (translation)	What is said (original)
42	Jakob	When you have been able to draw that triangle, you choose the third one from the right (*refers to the menu bar in Cabri*)	Når dere har fått tegnet den der trekanten så går dere til den tredje fra høyre (*viser til menyraden i Cabri*)
43	Students	(*Much noise*)	(*Mye støy*)
44	Jakob	[Now you have to be attentive, Tone! You have to be attentive]	[Nå må dere følge med, Tone! Nå må dere følge med]
45	Tone	Yes	Ja
46	Jakob	Then you choose the third from the right which is denoted cm (*refers to the menu bar and the icon referring to Distance and Length*), it says. If you click on that one, you will have a pull down menu. And it says angles. Then you choose the one called angle.	Så går dere på den tredje fra høyre dere det står sånn cm (*viser til menylinja i Cabri og ikonet som referer til måling av avstand og lengde*), står det. Hvis dere trykker ned den, får dere opp en rullemeny. Så står det vinkel. Så velger dere den som heter vinkel
47	Arve	Yes	Ja
48	Jakob	And that one is used in the following way. We first choose one of the laterals of the angle. So if we will measure this angle (shows angle *A on the triangle he has drawn in Cabri*). If you look here. If we want to measure this angle here. Then I first make a click on one of its laterals, then one its vertex and then I click on the second lateral of the angle. Can you see? Then such a number appears.	Og den bruker vi på følgende måte. Vi velger først et av vinkelbeina. Så hvis vi skal måle den her vinkelen her (*Viser til vinkel A på trekanten han har tegnet i Cabri*). Hvis dere ser. Hvis vi skal måle den her vinkelen her. Så trykker jeg først på et det ene vinkelbeinet, så på toppunktet og så trykker jeg på det andre vinkelbeinet. Ser dere? Så kommer det et sånt tall her.

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 2

Jakob's technique is the more general technique used when measuring angles between lines and thus what I denotes as a special technique to use when measuring angles in a triangle where he did not utilise the already made points *C* and *B.* Jakob's technique is illustrated below in Figure 6.7 where $\angle CAB$ is measured and the marks on AC and AB were made when the angle was measured:

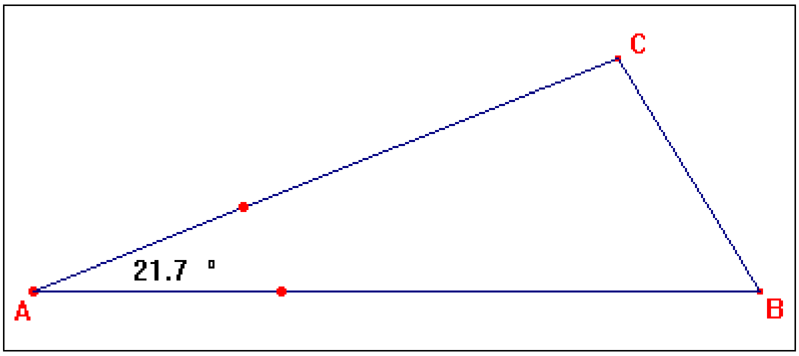


Figure 6.7: Illustration of Jakob's technique for measuring angles

The *technique* Jakob presented for successful measuring of angles in a triangle with Cabri worked well for some of his students, but during the lesson I observed that several of his students experienced problems with the technique. A problem was that several students ended up making a large number of points on the laterals of the triangles and not just one at each which I illustrated in Figure 6.7. This made their figures difficult to work with. A more critical problem was that Jakob's technique unintentionally obstructed students from what I experience as an affordance in Cabri: that it offers its users practice in using the *standard notation for defining angles* applying the three corners it connects. However, because of Jakob's different technique it more appeared like a negative constraint with Cabri.

After an intermediate period, which included utilisation of the dragging-function to adjust angles (see Episode 3, p. 212), Jakob asked his students to consider what the sum of their three angles would be (see Episode 4 below). Near the end of utterance 59, Jakob introduced the possibility to use a calculate-affordance in Cabri saying "I can use Cabri to add something for me!":

Ut	Who	What is said (translation)	What is said (original)
57	Jakob	What I am considering now, is to know what is, if I add the three angles together. What will I have then? Is there anybody who knows what I have then?	Det jeg er litt interessert i nå, er å vite hva er, hvis jeg plusser de tre vinklene sammen. Hva får jeg da? Er det noen som vet hva jeg får da?
58	Emil	180	180
59	Jakob	180? Can that be correct? If I now make some simple numbers (*uses the dynamic dragging-function to drag in the corners of the triangle*). 50 and 50 and 80. 50 and 50 are 100. Plus 80 are 180. Yes, it looks correct. But, I can use Cabri to something more! I can use Cabri to add something for me!	180? Kan det stemme? Hvis jeg lager litt greie tall nå (*drar i hjørnene på trekanten*). 50 og 50 er 100. Pluss 80 er 180. Ja, det ser rett ut. Men, jeg kan bruke Cabri til noe mer! Jeg kan bruke Cabri til å legge sammen noe for meg.

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 4

Immediately after this episode, a number of Jakob's students responded arguing for other answers than 180 (one of them with 296). Jakob did not exploit these mistakes any further, but instead introduced the *calculate* affordance in Cabri and its location in Cabri's menu bar (see Appendix 8xix, p. 351). Jakob emphasised use of the dragging-function and the measure-affordance combined with the *calculate*-affordance in Cabri as an aid to explore the sum of angles in a triangle. The plenary ended when Jakob demonstrated that the sum in the "Calculate"-window remained 180 despite his dragging in one of the corners of his triangle (see Appendix 8xx, p. 352). One and a half minute later he claimed the following: "regardless of the form of the triangle, the sum of the size of its angles is 180 degree, neither more nor less". This lesson illustrates Jakob's focus on *utilisation of the measure- and calculates affordances to test* a hypothesis concerning the sum of angles in a triangle, and his utilisation of the dynamic dragging-function to add to the *verification* of the results.

In this subsection, analytical findings indicate Jakob and Frode's focus on utilisation of the dynamic dragging-function, measure- and calculate affordances, and to utilise the dynamic dragging function to check whether a technique was utilised successfully. For example, constructions were considered to be successful when the size of angles was unchanged after *moving* a line with the dynamic dragging-function.

Overall, analytical findings in this section (6.1.3) reveal that Jakob and Frode's orchestrations of students' Cabri use had a focus on *development of successful techniques with Cabri, affordances* and *utilisation of affordances in Cabri* such as the measure-, calculation- and dynamic dragging-function. In particular the findings indicate that these two focuses, techniques and affordances, went alongside each other. The latter is evident when for example, in the review of the Cabri test, Frode focused on use of the dynamic dragging-function to check whether a construction had been done accurately, in other words utilising an affordance to check techniques in Cabri: If the constructed objects still were connected after using the dynamic dragging-function in Cabri, it was a strong indication for a successful construction. Thus, the teachers' utilisation of the dynamic dragging-function had an emphasis on *testing* and often used in combination with the calculate and the measure affordances. This kind of utilisation of the dynamic dragging-function is discussed further in Chapter 7 (see Section 7.3.1, p. 281) and compared with Trude's utilisation of the same affordance.

6.1.4 Style of teaching and the role of teaching operations

Above in Section 6.1.3, two main focuses in Jakob and Frode's orchestrations of students' work with Cabri have been emphasised: Development of successful techniques in Cabri and affordances in Cabri where the latter also included utilisation of these affordances. What characterised Jakob and Frode's teaching of these two focuses? Analytical findings in this subsection illustrate a number of 'teaching operations' exploited by the teachers and a 'style of teaching' which I denote as being *supportive* and *step by step* based where the teachers posed questions and sometimes *intervened*. Teaching operations and intervention as terms in this thesis were introduced in Section 2.3.2. Teachers' style of teaching has been addressed in many research papers considering use of ICT in mathematics teaching, and a number of these are mentioned in Section 2.2.4 in the literature review.

On the coming pages I refer to the same list of events as in Section 6.1.3 (see Table 6.3, p. 206) and many of the same episodes are considered. This has been done deliberately to indicate the relationship between teachers' style of teaching, the role of their teaching operations and what they wanted to achieve. The latter was emphasised in Section 6.1.3 while teachers' style of teaching and teaching operations are considered in this section.

Jakob and Frode's styles of teaching in Cabri-lessons

In the literature review I quoted Kerr (1996) arguing that introduction of technology use makes changes in teaching style necessary but that a large number of research papers have reported minimal changes in teaching style and rather a consistency of style such as in Cuban et al. (2001), Kendal and Stacey (2001), Crisan et al. (2007) and Monaghan (2001). Both in Monaghan and in Kendal and Stacey it is indicated that criteria for such changes rather are rooted within a teacher's typical style of mathematics teaching which is not changed just by bringing in computer software or other kinds of ICT tools in mathematics teaching. In this subsection I consider Jakob and Frode's style of teaching when using Cabri briefly comparing with their teaching with compasses to indicate possible consistency and differences in style of teaching.

Frode's teaching both with compasses and Cabri was composed of teacher led plenaries and working periods where his students were assisted by Frode. In his plenaries with compasses, I observed that Frode repeatedly invited the students to contribute in his plenary accomplishment of tasks. Below I give an example concerning construction of a perpendicular through a point on a line which was considered in the two consecutive lessons. Frode's style of teaching when accomplishing this construction with compasses is illustrated in the dialogue between Frode and one of his students, Bent, in Episode 2 from one of his lessons with compasses (see p. 207). In the consecutive Cabri-lesson, Frode once again was leading the plenary and asking his students for contributions supporting the consistency-claim in the quoted research in the previous paragraph. The consistency and his suggested way of teaching was also addressed by Frode in a workshop session. In Episode 11 from LCM

Workshop 11, presented in Section 6.1.5, p. 231, Frode talked about his teaching with Cabri and in mathematics in general. The workshop took part approximately one month after his teaching with Cabri came to an end. In that episode, he referred to his *typical* way of teaching more in general: He, usually upfront in the classroom accomplishing the plenaries, wishing to have contributions from as many students as possible. However, Frode admitted that it was often just himself and a few of his students who contributed.

Although I observed an overall consistency in Frode's style of teaching in his Cabri and compasses lessons, his plenaries with Cabri appeared to be shorter and with fewer questions from Frode to his students. As an example, during the first 10 minutes in his lessons with Cabri on the 18th of January, Frode presented how to accomplish the same construction with Cabri as considered in the previous lesson with compasses (see Episode 4, p. 208). Frode's style of teaching appeared similar to what I later denote as Jakob's *supportive step by step orchestration* of Cabri-lesson (see p. 221). When Frode began the Cabri-lesson, he expressed this expected pattern of work to his students in the following way. The students were sitting next to one computer each:

Ut	Who	What is said (translation)	What is said (original)
1	Frode	We do this together. We do it simultaneously, while I do it at the blackboard by the projector (*he refers to his presentation of Cabri-use visible on the screen through the projector attached to his computer upfront in the room*), you do it at the same time in such a way that all of you do it.	Vi gjør dette her sammen. Vi gjør det samtidig, mens jeg gjør det på tavla, på prosjektøren (*han viser til bildet fra projektoren tilknyttet hans PC foran i rommet*) gjør dere det samtidig slik at alle får gjort dette.

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio, Episode 1

The students were supposed to repeat Frode's techniques with Cabri, and I observed that five minutes after ending the plenary most of his students had managed to do the construction.

Beyond leading plenaries, Frode orchestrated students' use of Cabri by *walking around* and *assisting* students at the computer lab. In most of Frode's Cabri-lessons, students' work with Cabri was guided by the *worksheets* in the teaching package (see Section 6.1.1) and it was within that frame that Frode assisted and sometimes intervened in plenary typically related to his emphases (see Section 6.1.3).

Frode's style of teaching when assisting his students during their work with tasks in the teaching package appeared very similar to Jakob's style. However, I observed that Jakob's plenaries, both when using compasses and Cabri, typically were shorter than Frode's often only one or two approximately 1 minute's plenaries during a 45 minutes lesson. I also observed two longer Cabri-plenaries. One was Jakob's review of the Cabri-test in February which was the only lesson observed in Frode and Jakob's classes where one of the students led any plenary. The student accomplished the constructions which were presented on the video screen through the projector. Jakob gave some questions and instructions to the student, and Jakob was placed upfront in the room several times pointing to the video screen. Jakob also explicitly several times invited the other students to contribute to the review by asking questions concerning the accomplishment of the tasks in the test. The other longer plenary was in one of his Cabri-lessons (Event 15) where the first half of the 45 minutes lesson was accomplished as a plenary. This lesson is considered below.

He started the lesson by informing students about the main content of the lesson: To construct triangles and find the sum of angles in triangles. Then Jakob introduced the students to the *working form* of the following part of the lesson: the students were supposed to repeat his successful techniques from the plenary. I argue that his suggested pattern of work in this plenary was similar to Frode's described above and could be characterised as a *step by step* orchestration of Cabri:

Ut	Who	What is said (translation)	What is said (original)
23	Jakob	You can repeat exactly the same as I do now. Then we can do it quicker (*3 seconds pause*). Open your Cabri .(*8 seconds pause*)	Da kan dere gjøre akkurat som jeg gjør nå. Så gjør vi det litt raskere. (*3 sekunds pause*). Åpne Cabri.(*8 sekunds pause*)
24	Jakob	Start with a segment (*12 seconds pause*). Start by drawing a segment. You find segment on number three from left (*refers to the menu bar in Cabri*). Click down the button, then you will see that the segment appears.	Start med linjestykke (*12 sekunds pause*). Begynne med å tegne et linjestykke. Dere finner linjestykke på nummer tre fra venstre (*viser til menyraden i Cabri*). Hold nede knappen, så ser dere linjestykke dukker opp.

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 1

In most of the Cabri-lessons I observed, Jakob's plenaries were much shorter and typically related to work with the worksheets in the teaching package which was used in most of the lessons (see Section 6.1.1). As mentioned there, Jakob described these worksheets as having a *step by step nature* (see page 198).

In his teaching, Jakob usually had a brief introduction mentioning what the students were supposed to do, referring to the worksheets and accomplished one or two interventions in plenary during students' work with Cabri. These interventions typically appeared when I observed that his students used a *technique* that he did not experience as successful in Cabri. His interventions often started by assisting *single* students but when several students used an unsuccessful technique, he often intervened by giving a *plenary* orchestration of students' work. Episode 1, from his Cabri-lesson on the 17th of January (see p. 210), is an example of such an intervention which I observed occurred after several of the students were unsuccessful in their construction of 60 degree angles. He had started off the same lesson by informing in plenary that the students were supposed to continue with their work with Worksheet 3 in the teaching package, handed out in the lesson one week earlier. The students then worked with Cabri guided by the tasks on the worksheet, only interrupted a few times when Jakob intervened by giving plenary orchestrations.

In their plenaries, Jakob and Frode positioned themselves as the ones who commanded the instructions for their students with one exception: Jakob's review of the test. I end the section by considering whether the review of the Cabri-test could indicate a *shift* in Jakob's orchestrations of Cabri-lessons to involve students more in the plenary orchestrations? Or could the increased involvement of students rather be explained based on students being more experienced Cabri users? To address the issue of a potential shift in Jakob's style of teaching, I briefly consider Jakob's orchestrations in the following computer software lessons. In February 2006, a couple of weeks after ending his teaching with Cabri, Jakob used a spreadsheet package in several mathematics lessons. His teaching was supported by a written teaching package for use of spreadsheets designed by the same teacher as the teaching package used in most of the Cabri-lessons. Below, I briefly give comments to Jakob's plenary orchestrations in one of his spreadsheet lessons (see Event 29 in Table 6.3, p. 206). The task given to students was to make a budget for a fictitious school trip with five columns in the spreadsheet. "Date", "Item", "Income", "Expense" and "Balance" were the headings. The lesson started by Jakob handing out a copy of the teaching package to each of the students. The teaching package presented the layout for the spreadsheet they were supposed to design and instructions for making formulas. The students then worked with this task in the rest of the first part of the lesson. Jakob started the second part of the lesson by making the four headings and a number of lines with dates, different items, incomes and expenses without offering any oral communication. During the first 45 minutes, the students had designed or had been supposed to design a similar structure on their spreadsheet application, but without "Balance" as a column. Balance was not included in the teaching package so this was something extra added by Jakob. One minute into the second part of the lesson, Jakob called for attention directing students' attention to the new "Balance"-column:

Ut	Who	What is said (translation)	What is said (original)
16	Jakob	Can you see that I have made some changes? I have included an extra column which I have named “Balance”, there. Balance is how much we have on our account. Each time we make a withdrawal, Balance will be updated down here. Now I want to show you how you can make these formulas properly. But I wonder if I should give you some minutes to make this structure. And show you the formulas afterwards.	Ser dere at jeg har gjort noen forandringer? Jeg har satt inn en ekstra kolonne som jeg heter ”Saldo”, her. Saldo er hvor mye vi har på kontoen. Hver gang vi gjør et uttak kommer saldoen til å oppdatere seg nedover her. Nå skal jeg vise dere hvordan dere kan få disse formlene riktig. Jeg lurer på om jeg skal gi dere litt tid til å skrive opp dette her først. Og så viser jeg formlene etterpå.

Event 29, Feb 21st 2006, Austpark, Jakob, Excel, Computer lab, Video, Episode 1

After students had been working for approximately ten minutes, Jakob intervened (see Appendix 8xxi, p. 353) calling for attention. He used a couple of minutes in plenary explaining what was meant by “Balance” and how to create the formulas with cell references. After this intervention from Jakob, the students worked with their own spreadsheet for the rest of the lesson assisted by Jakob and an assistant teacher at the computer lab. This brief sketch of one of Jakob’s lessons with spreadsheets indicates a recognisable pattern in Jakob’s orchestration compared to his lessons with Cabri. The exception observed in Jakob’s review of the Cabri-test was not repeated in any of the observed spreadsheet lesson either in the classroom with laptops (as in the review of the test) or in the computer lab.

Most of both Jakob and Frode’s Cabri-lessons were dominated by orchestrations of students’ use of the teaching package. A slight difference was observed in Jakob and Frode’s lessons which appeared to be a matter of generality in their style of teaching. Jakob explicitly in sessions argued that he wanted only *brief* plenaries in his teaching, which in Cabri-lessons mainly had the form of brief introductions and interventions when several students had problems succeeding with tasks in Cabri. Frode in general accomplished *longer* plenaries than Jakob both when using compasses and Cabri and admitted that he *preferred* to be in control in his teaching. His students were typically expected to repeat his techniques either in parallel with Frode or immediately afterwards (illustrated in Episode 1, p. 220).

Both the teachers accomplished what I have denoted as *step by step* orchestrations of students’ work with Cabri, and they assisted their students by going around in the teaching room typically repeating the same emphasis as in their plenaries. I did not observe any big differences in each of the teachers' teaching style in their lessons with the two tools. This claim is also supported by teachers' own comments and observations of what I have denoted as their co-ordinated use of compasses and Cabri (see Section 6.1.2). They focused on addressing similar content and working pattern with the two tools, which in fact Frode in a session reported as being "quite satisfied with" (see Section 6.1.2, p. 203). Thus, findings in this subsection support *consistency* in Jakob and Frode's teaching style in accordance with the quoted research papers on page 219.

Teachers' teaching operations in Cabri-lessons

In the introduction to Section 6.1, I referred to Section 2.3.2 where I introduced 'teaching operation' as a term in my research study. I claimed that, in my study, I was able to observe teaching operations in Cabri-lessons through teachers' instructions and questions, and I argued that teachers' teaching operations are related to aids developed by the teachers to orchestrate students' work.

In this subsection I present analytical findings concerning the role and nature of Jakob and Frode's teaching operations based on observations of lessons with Cabri and compasses. The findings indicate that a number of the teaching operations used in their Cabri-teaching had a *general* nature, not particularly related to use of Cabri, such as asking counter questions, speaking with increasing voice level and repeating or rephrasing students' comments. Other teaching operations are particularly *related to use of Cabri* and computer software in general such as numbering icons in the menu bar in Cabri for reference, pointing and tracing with fingers at the computer screen, taking possession of the computer mouse and introduction of terms such as 'fix', 'hook' and 'glue' to support their emphasis on techniques. The teachers also utilised their co-ordinated use of Cabri and compasses as a teaching operation in itself when referring to lessons with compasses in Cabri-lessons.

I first consider what kinds of teaching operations Jakob utilised in two of his Cabri lesson (see Events 15 and 17) and compare with some of his lessons with compasses and Frode's lessons. Jakob utilised a number of *general* teaching operations in his plenaries. *Enthusiasm* and *speaking with increasingly voice level* are two such examples. Enthusiasm was utilised in Episode 1 in his 17th of January lesson with Cabri (see Section 6.1.3, p. 210). Besides emphasising the importance of being accurate when using Cabri, Jakob expressed *satisfaction* about the dragging-function in Cabri. He expressed loudly "Yeahh!!" and "Clever!", where the latter comment referred to Cabri as a clever tool. Several students responded by giving applause. When Jakob introduced the dynamic dragging-function in his lesson one week ahead of the 17th of January lesson, Jakob *enthusiastically expressed* "Can you see that it changes?” and “Can we mange it?” as teaching operations probably to highlight this affordance in Cabri for the students (see utterance 56, p. 212). Later in the same lesson, Jakob again spoke with an *increasing voice level,* this time concerning how Cabri afforded its users the possibility to calculate the sum of angles (see utterance 59, p. 217).

Frode too utilised increasing voice level when he presented affordances in Cabri. Here I consider an example from his 18th of January lesson (see Appendix 8xxii, p. 353). The episode is from a plenary where Frode presented how to write describing text in Cabri. When he presented this affordance, Frode utilised *loud voice speaking* as a teaching operation when he said “Choose text” and simultaneously chose the option in the menu bar. (It should be mentioned that in Norwegian language, the menu option “Text” is named “Skriv kommentar” which translated to English means “Write a comment”. There are obviously differences in how descriptive these two ways of labelling the menu options are for the students, but this difference is not considered further in this thesis).

When I considered Jakob and Frode’s teaching style in the previous subsection in this section (6.1.4), I argued for a minor difference between Frode and Jakob’s style. Frode in general held longer plenaries with himself in a leading role where he wanted his students to contribute. This was for example evident when I observed both his lessons on the 18th of January such as in Episode 2 (see p. 207) from his lesson with compasses and Episode 4 (see p. 208) from his Cabri-lesson. In the episode from his lesson with compasses, Frode asked for such contributions when demonstrating construction of a perpendicular with compasses and got a response from Bent, one of his students. Bent tried to contribute to Frode’s demonstration and in the conversation Frode utilised *repeating* and *rephrasing* of Bent’s suggestions as teaching operations. When Bent said: “keeping the same length”, Frode replied by rephrasing saying: “Keeping the same compass length, yes”. Few seconds after utterance 51, Bent used the rephrased term “same compass length”, to which Frode responded with “Correct”. These teaching operations also emphasise use of *established terms* in geometry, like intersection point, line, segments and perpendicular. Later in the lesson (see Appendix 8xxiii, p. 354), one of his students, Ivan, contributed and introduced “half moon” as a term. Frode commented to the use of this term by saying “Well, we do not use the concept half moon, but okay. It is a part of a circle, an arc.” Although Frode emphasised precise use of terms, he acknowledged Ivan’s term which illustrated the drawing created on the blackboard.

The episode above also exemplifies how Frode used *reference to a successful technique* with Cabri as a teaching operation. In the following Cabri-lesson, Frode raised a question concerning whether the students remembered how they made the perpendicular through a point on the line in the lesson with compasses. Some seconds later, Frode *rephrased* his question emphasising a line and point *A* as a starting point for the construction (see Appendix 8xxiv, p. 355). He asked Knut for an answer, and after a while Knut referred to intersection point as crucial. In this episode, Frode *referred* to their earlier use of compasses. Knut gave an answer indicating that he was aware of the shape of a perpendicular, but he could not at the moment describe how to construct one.

A few seconds after Episode 3, Frode introduced yet another teaching operation in his orchestration of students' use of Cabri. Near the end of utterance 20 in Episode 4 (see p. 209), the term 'fix' was introduced. By *fix* he refers to the technique to use in order to draw the circumference through a particular point and Frode emphasised *appearing text* as a *guarantee*. In fact, Frode's use of the term *fix* appeared similar to Jakob's use of 'hook' and 'glue'. *Hook* was utilised by Jakob commenting about being careful with the *mouse-pointer* and *move* the pointer in order to *hook* the circle on a point (see p. 210). I never observed Jakob utilising the term 'glue' in his teaching but he used it in a contribution in ICTML Workshop 7 (see Appendix 8xxv, p. 355). In this session he illustrated students' problems concerning technique with the mouse pointer with the term *glue* when wanting a circle to pass through an already made point.

So far I have mainly considered examples of Jakob and Frode's teaching operations in plenary sessions at the computer lab. In this paragraph I illustrate a consistency in Jakob's teaching operations in a plenary and when he later assisted his students in their work with Cabri. I refer to his 10th of January lesson (see Event 15). In his plenary (see utterance 24, p. 221), Jakob utilised *numbering of icons* on the menu bar as an aid and teaching operation when, in plenary, he introduced students to work with Cabri. Several times when I later observed Jakob assisting his students in using the menu bar in Cabri, he utilised numbering of icons on the menu, either from left or right, as a teaching operation. In utterance 24 he numbered the icons from left to right, while he numbered in the opposite direction from right to left two minutes later in his plenary (see utterance 46, p. 216). I interpret this choice to have been made according to whatever direction the wanted icon was closest. I also observed Jakob utilising this teaching operations in other Cabri-lessons, while I never observed Frode utilising a similar operation in his lessons.

Pointing at the screen and the menu bar in Cabri and sometimes tracing the suggested move with the finger were utilised both by Jakob and Frode as teaching operations in several Cabri-lessons including Jakob's mentioned lesson in the previous paragraph. They also sometimes took *possession* of the computer mouse, although the teachers in conversations mentioned this as being inadequate and Frode argued that he needed to be better at keeping his arms behind his back. In fact, Jakob did also utilise pointing as a teaching operation in the review session of the Cabri test. This was the only lesson where he placed himself in front of the room where pointing with finger could be done efficiently since one of his students was in charge of Cabri.

In the first subsection of this section (6.1.4), I presented analytical findings indicating that both Jakob and Frode's style of teaching were dominated by what I denoted as *supportive step by step* orchestrations of students' use of the teaching package. The extent and form of their plenaries had a minor difference, as indicated in a summary (see p. 223), but both of them used plenaries as an aid in *introductions* to lessons and to *intervene* when observing that several of the students had problems to succeed a particular task in Cabri. In the second subsection, I have indicated the role and nature of the two teachers' teaching operations. Both of them utilised a number of teaching operations which appeared to be related to their style of teaching. Frode, who preferred to be in control in his lessons and in general accomplished longer plenaries, often utilised teaching operations as *repeating* and *rephrasing* of students contributions. Both of them utilised *loud voice speaking* and Jakob talked *enthusiastically* about utilisation of affordances in Cabri. When I observed the two teachers assisting their students in the computer lab, they both utilised *pointing* with finger to the screen, *tracing* proposed computer mouse moves and even *possession* of the computer mouse as teaching operations. Jakob also used *numbering* of icons on the menu bar as a teaching operation supporting his orchestrations of students' use of Cabri. They also introduced *fix, hook* and *glue* as terms to pay attention to successful techniques and utilisation of affordances in Cabri. Thus in this section (6.1.4), teachers' style of teaching and use of supporting teaching operations have paid attention to how teachers' orchestrations of students' use of Cabri was accomplished.

6.1.5 Teachers' comments on their Cabri-teaching

Analytical findings in Sections 6.1.1 and 6.1.2 illustrated two pillars in Jakob and Frode's arrangements for their use of Cabri in teaching. The two pillars were use of a teaching package in most of their Cabri-lessons and co-ordinated use of Cabri and compasses. In Sections 6.1.3 and 6.1.4 I presented analytical findings concerning focuses in their teaching, successful techniques, affordances and utilisation of affordances, and how their orchestrations were accomplished with teaching operations in their Cabri-teaching.

Teachers' arrangement for use of Cabri, their focuses in teaching and the nature of their teaching give me a basis for interpreting what the teachers wanted to achieve, their goals, which energised their orchestrations. In this section (6.1.5) I add an extra dimension to the analysis by emphasising teachers own considerations in sessions when they talked about achievements during their Cabri-teaching. Below I list the three main areas of analytical findings presented in Section 6.1.5:

- Teachers' expressed experiences with their Cabri-teaching.
- The role of inquiry when teaching with Cabri.
- How the teachers experienced students' achievements with Cabri.

Findings in this section support already presented findings in Section 6.1.2 indicating that Jakob and Frode overall experienced their use of Cabri as a success. They expressed satisfaction with their teaching by indicating that their students liked to work with Cabri and mentioning the good achievements by students in two Cabri-tests at Grade 8 and in a review at the start of Grade 9. They used expressions such as success, positive effect and great efforts when describing students' work and achievements with Cabri. They also considered their co-ordinated use of Cabri and compasses as a good choice, with only one mentioned exception (see Section 6.1.2, p. 204). Jakob and Frode also argued why they did not interpret their teaching with Cabri to have involved inquiry where reference to the two pillars guiding their teaching (see sections 6.1.1 and 6.1.2) were used as arguments. They rather suggested working with more investigative and inquiry oriented tasks in a later phase of students' work with Cabri and not in an initial phase for both students and teachers. As evident from earlier chapters, inquiry in mathematics learning and teaching had been central in the developmental projects and in discussion in different sessions with teachers.

In this section (6.1.5), I present analytical findings based on analysis of data from conversations, meetings and workshop sessions where the teachers talked about their teaching with Cabri. Analysed data is both from within the process of using Cabri and particularly afterwards when the teachers considered and talked about their achievements with Cabri like at the KUL conference (see Event 38). Below, in Table 6.4, I present a table with the six events discussed in this section:

Table 6.4: List of events considered in subsections to this section (6.1.5)

Event	Date	Type of sessions
16	11.01.2006	LCM Workshop 10 at UiA
27	07.02.2006	Conversation with Frode at Austpark
30	22.02.2006	LCM Workshop 11 at UiA
31	09.03.2006	End of Cabri-use interview at Austpark
34	29.03.2006	LCM/ICTML Focus group interview at Austpark
38	05.09.2006	Austpark's KUL conference presentation at UiA

Teachers' expressed experiences with their Cabri-teaching

Below several examples are offered to highlight how Jakob and Frode experienced their role as teachers when teaching with Cabri. Overall, Frode expressed that it had been *fun* but *demanding*, and expressed the *challenge* of keeping his hand at the back or at least just *pointing* to the screen with his finger when assisting his students during work with Cabri. The latter are in accordance with my observations of his teaching operations presented in Section 6.1.4. Jakob emphasised how the *structured tasks* in the teaching package had helped him in orchestrating his teaching by *controlling* and *supporting* students' work with Cabri well in an *early* phase. They both argued that to use the package in teaching *relieved the pressure* on themselves as teachers inexperienced with Cabri. These findings support the analytical findings in Section 6.1.1 indicating that the teachers wanted to use the teaching package because of at least four reasons (see Section 6.1.1, p. 199). Like in Section 6.1.4, findings in this subsection indicate that, with minor adjustments, the teachers maintained their style of teaching in Cabri-lessons close to their style in other mathematics lessons.

In a number of sessions, Jakob and Frode gave comments about their experiences when supporting students' work with Cabri. In the end of Cabri-use interview in March, Jakob, Frode and Harald talked about their first ever teaching experience with Cabri earlier the same year. Based on a question concerning how they had experienced their teaching with Cabri, Frode contributed emphasising that teaching with Cabri had been *demanding* but at the same time *fun*. He added the *relief* of having student teachers[28] available when the number of questions from students increased:

Ut	Who	What is said (translation)	What is said (original)
624	Frode	… And I have had student teachers and that has been good.	….Og jeg har hatt studenter og det har vært greit.
625	Ingvald	Yes.	Ja.
626	Frode	and I would not really have made it on my own. The number of questions was so big. It is quite demanding because many students wonder about and ask questions.	og det hadde jeg nok ikke klart bare meg selv altså. Det ble såpass mange spørsmål underveis at. Det er ganske sånn krevende i forhold til, at mange elever lurer på ting og spør.
627	Ingvald	Mm.	Mm.
628	Frode	Perhaps more than in the classroom. But fun, yes!	Kanskje enda mer enn i klasserommet. Men gøy ja!

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 15

The interview continued with a contribution by Jakob where he referred

[28] Austpark is one of many schools in the local region where leaders had signed contract with UiA for fulfilling the responsibility of student teacher's compulsory education programme. Frode was one of the practice teachers at Austpark.

to their use of the teaching package. He expressed a benefit with the package: The big relief of having *good tasks* in the teaching package which with its instructions also served a desirable role of *controlling* students work with Cabri. He substantiated his argument by expressing that he found “it a bit uncomfortable” if students work too open. Although it is not clearly said here, his comment about feeling uncomfortable if students are working “too open” does not seem to be particularly related to use of Cabri:

Ut	Who	What is said (translation)	What is said (original)
632	Jakob	I think I like to have such proper tasks. I have to, I am dependent on having some good tasks which they can work with	Jeg tror jeg synes det er greit å ha ganske sånn greie oppgaver. Jeg må jeg er avhengig av å ha noen gode oppgaver som de skal jobbe med.
633	Ingvald	Yes. Different kinds of tasks than those you perhaps find in a [textbook](*interrupted*)	Ja. Litt andre typer oppgaver enn det du kanskje finner i en [lærebok] (*avbrytes*)
634	Jakob	I feel that I really wish to have some control on what they are doing. Because if they work too open I find it a bit uncomfortable. But it is a bit about daring to take the risk and [just]	Jeg føler veldig for at jeg ønsker å ha litt kontroll på det som de skal gjøre. At hvis det blir for fritt og åpent så synes jeg det kanskje er litt ukomfortabelt. Men det er jo litt det med at en må jo egentlig tørre å [bare]
635	Harald	[Mm]	[Mm]
636	Jakob	give away the control	gi fra seg kontrollen
637	Harald	Mm.	Mm.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 16

Although it is not clearly stated in these utterances, from the earlier discussion in the interview it is quite evident that he referred to tasks in the teaching package. Similar comments about experienced benefits with the teaching package were also expressed some weeks earlier in a workshop session (see Section 6.1.1, p. 198). There Jakob argued for benefits of using tasks in the package which *relieved the pressure* on him as the teacher in an early phase of work with Cabri.

As indicated in Section 6.1.4, Frode talked about his style and role as a teacher many times both concerning his mathematics lessons in general and in particular when using Cabri. In LCM Workshop 10, taking part at an early stage of their teaching with Cabri, Frode expressed his first experiences from assisting students with Cabri at the computer lab. Frode emphasised the importance of not taking possession of the *computer mouse* and expressed that keeping his hands at the back was a challenge. To *point* with his finger at students’ screens was as far as he wanted to constrain students’ work with Cabri; it was his preferred *teaching opera-*

tion when assisting students with Cabri at the computer lab:

Ut	Who	What is said (translation)	What is said (original)
445	Frode	And something I really have to keep in mind as a teacher is to practice having my hands on my back	Og det er det en må trene mest på som lærer det er og så holde hendene på ryggen.
446	Aud	Yes	Ja.
447	Frode	Agree? (*laughter*)	Ikke sant? (*latter*).
448	Aud	It is true	Det er sant det.
449	Frode	Or at least pointing at the screen	Eller i hvert fall peke på skjer-men
450	Jakob	Mm.	Mm.
451	Aud	Yes	Ja.
452	Frode	and not take possession of the mouse	og ikke ta tak i musa!

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 15

Pointing was observed as a teaching operation utilised much in both Frode and Jakob's Cabri-lessons (see Section 6.1.4).

In LCM Workshop 11, six weeks later, a slightly different aspect with their teaching was brought up in a group session where particularly Frode and Trude contributed. They discussed how challenging they experienced the process *of stimulating good conversations* in mathematics lessons. Frode considered critically his teaching and how he experienced the usual kinds of conversations in his mathematics lessons. Frode argued that the conversations in his teaching typically were between himself and only a *few* students, while the rest of his students needed strong pushes to participate in the conversations:

Ut	Who	What is said (translation)	What is said (original)
465	Frode	And the conversations in my class, at least quite often, are between myself and three to four students	Og så er samtalen ofte i hvert fall i klassen som jeg har så det går mellom meg og så og tre fire stykker.
466	Trude	Yes	Ja
467	Frode	which are active the whole time.	som er med hele tiden.
468	Trude	Yes	Ja
469	Frode	And the rest I have to push really hard in order to have inputs from them.	Og så de andre må jeg dra i vel-dig hvis en skal få noe ut av dem.
470	Trude	Mm.	Mm.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 11

I have described Frode's style of teaching to be characterised with many questions to his students and with a desire for him as the teacher to have contribution from the students in his own led plenaries (see Section 6.1.4). However, it was evident in my observations that mainly the same 2-4 students contributed each time. Thus, Frode's comments in the episode above relate well to findings in Section 6.1.4 but his comments also indicate that he was not pleased with the low numbers of active students in his plenaries. Jakob too considered his own role as teacher, like the desire for controlling students' work with Cabri by not having a too open structure as indicated earlier in this section.

Above several examples have been presented to indicate how the teachers experienced their role as teachers when using Cabri. Teachers' comments support well observations and findings presented in earlier sections in this chapter particularly related to the observed teaching operations considered in Section 6.1.4. Many of the reasons teachers expressed for using the teaching package ahead of their teaching with Cabri were also repeated after their teaching. The teachers particularly emphasised the package's advantages in an early phase of work with Cabri for both teachers and students and how it controlled and supported students' work well. Overall, both of the teachers expressed that teaching with Cabri had been fun but demanding. The teachers also expressed some concerns about their style of teaching in Cabri-lessons and in general. They commented respectively to dare giving away control and being able to stimulate more engagement among all the students. Thus, these comments indicate a developing awareness of possibilities with Cabri and their teaching more in general, but that they experienced a need to control students' work in the initial phase of work with Cabri.

The role of inquiry when teaching with Cabri

In the developmental projects, the role of inquiry and what inquiry could mean for teaching and learning of mathematics was discussed frequently for example in the workshops. Inquiry had an overall key role in the LCM project which aimed "to design and study mathematics teaching development for the improved learning of mathematics through inquiry communities between teachers and didacticians" (Jaworski, 2004b, p. 33). In the ICTML project, inquiry was related to use of ICT in mathematics teaching and learning.

When Jakob and Frode considered the *role of inquiry* in their orchestrated Cabri-lessons, their comments were often linked to *time* as a critical issue and to characteristics of the *tasks* in the teaching package used in their teaching. Frode and Jakob also discussed the role of inquiry in different *phases* of teaching with Cabri, and argued for not using inquiry in an early phase when both students and the teachers were newcomers with Cabri. As already emphasised, Jakob and Frode rather had a focus on students' development of successful techniques and affordances in Cabri. They argued that the teaching package, which, as mentioned, was characterised by the teachers as non-investigative and little inquiry based, gave good support in this process while inquiry and investigative tasks could be good in a later phase. In one of the workshops, didacticians questioned this interpretation and initiated a discussion of what inquiry could mean related to Cabri-use. During different sessions, other terms such as investigative tasks, open tasks, problem solving and work in groups were mentioned when the teachers talked about and interpreted inquiry in teaching.

Time as a critical issue for the teachers was discussed in Chapter 5 and mentioned in the literature review in Chapter 2. In Chapter 2 I quoted Assude (2005) who discusses time needed for students to get used to the tool and able to use the tool. Assude denotes this as the 'tool time' (see Section 2.2.4, p. 39) which she considers as being part of the overall 'time capital' in mathematics teaching. An example of how teachers analytically commented their teaching and use of time came in LCM Workshop 11. There they argued that inquiry was time consuming and not purposeful in an early phase with Cabri. Frode substantiated their non-emphasis on inquiry and Jakob added by arguing for their approach as being *time effective* in order for students' successfully learning of Cabri as a *tool*:

Ut	Who	What is said (translation)	What is said (original)
80	Frode	Yes, mm. Then we ran very little of inquiry as you are saying. Because I ran it very basic; in the classroom with compasses: Look here. See how I do then you are allowed to do it afterwards. While on the computer lab it was more like to show them and then they try it themselves and raise their hands and like so backwards and forwards between teacher centred and students collaboration.	Ja mm. Så kjørte vi som du sier veldig lite inquiry. For jeg kjørte veldig sånn der basic; i klasserommet med passer: Se her. Se åssen jeg gjør det så får dere gjøre det etterpå. Mens på datarommet så blir det jo litt mer vise så prøver de selv så rekker de opp hånda og litt sånn fram og tilbake med lærer styrt og elevsamarbeid da.
81	Some	Mm.	Mm.
82	Some	(*Someone clears his throat*).	(*Kremter*).
83	Jakob	I think it was important to use the time like that in order for them to learn the tool a bit.	Jeg synes det har vært viktig å bruke tiden sånn nå for at de skal lære verktøyet litt.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 2

Basically, these and other comments presented below indicate that Jakob and Frode's focus was on effective use of what Assude refers to as the tool time. Their two focuses in their orchestrations of Cabri-teaching (see Section 6.1.3) could in fact indicate that tool time was close to the total time used on Cabri at Grade 8.

In LCM Workshop 10 and 11 in January and February and later in their conference presentation, the *nature of the worksheets* in the teaching package with respect to inquiry was discussed. Below is a contribution from LCM Workshop 10 (see Event 16) where Jakob argued that the content in the worksheets did *not* have an *investigative* nature. Jakob added that he believed students would be able to use Cabri in a *more investigative way later,* but not as part of the process to learn using Cabri:

Ut	Who	What is said (translation)	What is said (original)
384	Jakob	…. So, those worksheets, their nature are not very investigative, they are really focused on letting the students try out the tool [and to achieve]	… Så de de kursarkene de er de er ikke sånn veldig sånn veldig utforskende av natur de er veldig sånn egentlig fokusert på å få prøvd verktøyet litte grann [og få]
385	Trude	[Yes]	[Ja]
386	Jakob	So I think after a while, when they have managed to accomplish and learnt the tool a bit, then they will be ready to use it a bit more investigatively.	Så jeg tror nok etter hvert når de har kommet seg igjennom og lært verktøyet litt så kan man nok begynne å ta det i bruk litt mer utforskende virksomhet da.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 13

What he seemed to argue was that because of its descriptive nature, the teaching package assisted the students in utilising the affordances in Cabri and development of techniques with Cabri. This interpretation of benefits with the teaching package supports the observed focuses in their orchestration of Cabri-teaching (see Section 6.1.3).

In LCM Workshop 10, neither Frode nor Jakob mentioned inquiry when they talked about the nature of the teaching package. However, six weeks later, in a group session in LCM Workshop 11, Jakob and Frode considered the nature of the package using the term 'inquiry'. An important reason for the emphasis on inquiry was that the discussion was situated within a session where the teachers had been asked to report from their teaching particularly related to inquiry in mathematics. In the session, Jakob concluded that the *tasks* in the package did *not* "look like inquiry":

Ut	Who	What is said (translation)	What is said (original)
426	Jakob	But if I consider the tasks which we handed out on the worksheets	men når jeg hvis jeg tenker på de oppgavene som de fikk ut på ark.
427	Otto	Yes Yes [Yes]	Ja. Ja [ja]
428	Jakob	[Then]	[Så]
429	Jakob	They do not look like inquiry	Ser de ikke veldig inquiry ut.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 10

What Jakob expressed in this episode seems very close to what he brought up in the discussion in LCM Workshop 10 six weeks earlier, but talking of inquiry *instead* of *investigative worksheets*. Early in the group session in LCM Workshop 11, Jakob and Frode expressed a reason why they did *not* characterise the Cabri-teaching to have involved inquiry: Students' had worked *individually* or in *pairs* with Cabri focusing on getting experiences with the *tool*.

Ut	Who	What is said (translation)	What is said (original)
20	Jakob	So I do not think that it has been inquiry, it has typically been tasks for single students or like in Cabri where they have been sitting in pairs. And now we have started to use Excel a bit. It has mostly been to learn it a bit like a [tool]	Så det har vært ikke så mye inquiry det har mer vært oppgaver for enkelt elever og eller det har sittet to og to elever da når de har jobbet med Cabri. Så har vi begynt å bruke Excel noe ja. Det har også mer vært å lære det sånn litt som et [verktøy]
21	Frode	[Mm]	[Mm]
22	Jakob	because they did not know it from before.	fordi det var ikke kjent for dem fra før.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 1

Parts of their contribution in the episode addressed organisation of students respectively in pairs and individually in Jakob and Frode's lessons. The emphasis on organisation of students when considering inquiry could indicate that the teachers interpreted inquiry as being collaborative work in consistency with how teachers themselves had been grouped when considering inquiry in workshops.

Overall, Jakob and Frode argued many times that the students needed to be experienced in using the software before using it as for example a problem solving tool or in inquiry. This was emphasised by Jakob in the end of Cabri-use interview in March (see Appendix 8xxvi, p. 356). In this episode Jakob argued that in order to do *problem solving* students had to be able to use Cabri, to "know the tool" as Jakob stated it. Such an emphasis on tool skills in the early phase of using a computer software tool is in fact quite typical and natural according to research literature quoted in Chapter 2. However, the teachers several times expressed that they did believe that inquiry could be appropriate in a *later* phase of work with Cabri. The latter was argued by Jakob in the earlier presented utterance 386 in LCM Workshop 10: "So I think after a while, when they have managed to accomplish and learnt the tool a bit, then they will be ready to use it a bit more investigatively" (see p. 234). In a group session in LCM Workshop 11, Jakob expressed a similar argument and two of the didacticians in the group, Otto and Aud, gave critical response to Jakob and Frode's interpretation of inquiry and suggested work with inquiry at a later stage. Otto challenged Jakob's argument (see utterance 93 in Appendix 8xxvii, p. 356): "Don't you think it is a bigger challenge to go from where you the whole time have got a detailed description on what to do, to find you own approach? That it in fact is a bigger step than to make out all the technical things". This comment from Otto indicates that he believed it was a bigger step for students to proceed from the phase of having detailed instructions to investigate the tool oneself than to get experience with the tool. Aud also asked if they believed they could *avoid* using inquiry in their teaching:

Ut	Who	What is said (translation)	What is said (original)
153	Aud	Are you saying that you did not use inquiry at all when you did things like this? (*Aud replies to teachers' description of their Cabri-teaching and their claim of very little inquiry in their teaching, see Episode 2*)	Sier dere at dere ikke har brukt inquiry i det hele tatt når dere har drevet med sånne ting som det? (*Aud svarer basert på lærernes kommentar om at Cabri-undervisningen har inneholdt lite inquiry, se også Episode 2*)
154	Frode	[Yes because]	[Ja for det]
155	Aud	[Can you manage]	[Kan en greie]
156	Aud	to avoid that?	å unngå det da?

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 6

Few minutes later Frode started to address his work with the teaching package in light of inquiry, emphasising that the students did discover things although he did not interpret the tasks as being "open tasks" (see Appendix 8xxviii, p. 356). Afterwards Jakob added to Frode's response referring to the *dynamic dragging-function* in Cabri (see Episode 9 below) as something he as a teacher could utilise in his teaching to *stimulate inquiry*:

Ut	Who	What is said (translation)	What is said (original)
349	Jakob	and to use the tool is in a way a kind of investigation of the tool [and]	og finne ut av verktøyet er på en måte utforskingen av verktøyet [og]
350	Frode	[Yes]	[Ja]
351	Jakob	when I assist them and borrow the mouse and make some dragging in the figure.	når jeg kommer bort til noen og får låne musa litt og drar litt i en figur.
352	Otto	Mm..	Mm.
353	Some	Mm..	Mm.
354	Jakob	Oh, what happened now? Why did it happen?	Ah, hva skjedde nå? Hvorfor skjedde det?
355	Otto	Yes, yes	Ja, ja
356	Trude	Mm..	Mm.
357	Jakob	and then, and then, and then I perhaps do not tell them how to do it so	og så ja, og så og så sier jeg kanskje ikke åssen de må gjøre det men så
358	Otto	[No]	[Nei]
359	Jakob	I rather tell them, okay this was not totally correct	Sier jeg kanskje okay dette her stemte ikke helt.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 9

In fact, awareness for their experienced non-use of inquiry, lack of investigative tasks or problem solving in an early phase of work with Cabri was not brought up for the first time in the quoted episodes from the workshop in February. In a brief conversation two weeks earlier but still some weeks after their teaching with Cabri, Frode took the initiative and argued that they rather should have given their students some “problem solving tasks” (see Episode 2 below). In utterance 15, he characterised the development of skills in using Cabri as the *secondary task*, while the ability to solve problems and work more investigative seem to be what he referred to as the *primary task*:

Ut	Who	What is said (translation)	What is said (original)
9	Frode	[What I meant is that Cabri… Well, I am really positive towards using Cabri.]	[Det jeg mente at Cabri… Jeg er veldig for å bruke Cabri.]
10	Ingvald	[Yes]	[Ja]
11	Frode	I do regard it as a very good piece of software. But I think perhaps that the way we used it not was so appropriate.	Jeg synes det er et veldig bra program. Men jeg tror kanskje at måten vi brukte det på ikke var så hensiktsmessig.
12	Ingvald	[Mm]	[Mm]
13	Frode	I think we rather should have given problem solving tasks.	Jeg tror heller at vi skulle gitt problemløsningsoppgaver.
14	Ingvald	It is difficult with developing sufficiently good facilities with the tool.	Det er vanskelig det der med å opparbeide seg verktøyferdighet som er god nok.
15	Frode	Yes because it is a secondary task which disrupts the primary really.	Ja for det er jo en sekundær oppgave som forstyrrer den primære egentlig.

Event 27, Feb 7th 2006, Austpark, Frode, Conversation, Audio, Episode 2

Supported by Jakob in their conference presentation seven months later, Frode described their teaching with Cabri during January 2006. They also considered how they wanted to proceed further with Cabri. In Episode 12 Frode expressed as a desire to develop teaching from what he regarded as being *deductive* to more emphasis on *investigations* for both teachers and students. This argument is more in accordance with his comments presented above than what he elsewhere had emphasised:

Ut	Who	What is said (translation)	What is said (original)
140	Frode	Yes, consequently the teaching last year was more deductive than inductive. Isn't that what it is called?	Ja, sånn at den undervisnings-formen vi hadde i fjor var mer deduktiv enn induktiv. Er det ikke det det heter?
141	Jakob	Yes	Jo
142	Frode	Perhaps not so investigative, we chose to do it so, but now we must try, both teachers and students, to work more investigative	Ikke så utforskende kanskje, vi valgte å gjøre det sånn og nå må vi prøve oss, både lærere og elever, å utforske mer.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 10

These comments indicate that the teachers wanted to use Cabri differently in 2007 when their classes entered Grade 9. However, Jakob's class was taken over by another teacher and data from Jakob's teaching in his new Grade 8 class in 2007 indicates that a similar use of the teaching package remained central when he introduced GeoGebra for this new class. Frode left his Grade 9 class during autumn 2006 for a new position at another school. This limited the possibility for a study of the longitudinal effects of introducing Cabri and is not considered in this thesis.

Analytical findings presented in this subsection indicate that the teachers did *not* interpret their Cabri-teaching to have involved inquiry although this was questioned by didacticians in a workshop session accompanied by a discussion. Lack of time was mentioned as one reason for not including inquiry in their teaching with Cabri. Jakob's comment about feeling uncomfortable if students worked too open (see p. 230) also indicates uncertainty to inquiry since he seemed to relate inquiry to open investigative tasks. During different sessions, terms like investigative tasks, open tasks, problem solving and work in groups were used when the teachers argued for not using inquiry. The teachers seemed to relate inquiry to *characteristics of the tasks* in the teaching package used in their teaching and which the teachers argued that did "not look like inquiry". Altogether these different comments from the teachers concerning inquiry indicate that the teachers did experience inquiry as a hard term to interpret in teaching.

Within and after their teaching with Cabri, Jakob and Frode emphasised the importance of students' developing their skills in using Cabri. They argued that the teaching package, which as mentioned was characterised by the teachers as non-investigative and little inquiry based, gave good support in this process while inquiry and investigative tasks could be good in a later phase. The role of inquiry in Jakob, Frode and Trude's teaching will be compared and analysed further in Section 6.2.5, Section 6.3.1 and Chapter 7.

Students' achievements with Cabri

In this subsection I pay attention to how Jakob and Frode experienced students' achievements related to use of Cabri. I refer to contributions where the teachers expressed concerns about students' background in geometry and students' lack of developing successful techniques in Cabri by them expressed as inaccurate use of Cabri. The latter was also considered in Section 6.1.3. However, the teachers did argue that their teaching had been successful: Their students' had enjoyed working with Cabri and also achieved improved results in tests with Cabri and compasses.

During the LCM/ICTML focus group interview in March 2006, parts of the discussion focused exactly on students' achievements with computer software weeks earlier. One of the didacticians present, Aud, asked whether the teachers had observed *changes* in *students' achievements* during the first two years of the projects. The teachers emphasised the complexity when considering students' learning, but Frode did refer to improved test results among his students after Christmas 2005. In the episode below, Frode speculated that Cabri and other computer software could have had a *positive effect* on this experienced improvement:

Ut	Who	What is said (translation)	What is said (original)
215	Frode	(…) on Grade 8, during this year students skills in mathematics have improved, I will not give the credit to someone, to KUL or any of us or anything, but at least something has happened this year	(…) åttende klasse da, i løpet av dette året her sånn, så har ferdighetene i matematikk gått oppover, jeg skal ikke gi kreditten til noen, til KUL eller oss eller noen som helst, men det har i hvert fall skjedd i år
216	Several	[Mm]	[Mm]
217	Frode	Especially after Christmas when we started to use Cabri and Excel and even when we have worked with another topic, division where we have not applied ICT, results on the chapter tests have been very good!	at spesielt etter jul med bruk av Cabri og Excel og til og med nå et emne vi har om divisjon etterpå som vi ikke har brukt IKT, så har resultatene på disse her kapittelprøvene vi har vært veldig bra!
218	Ingvald	Great!	Så fint!

Event 35, Mar 29th 2006, Austpark, LCM/ICTML interview, Audio, Episode 4

In their conference presentation half a year later, Frode characterised their implementation and use of Cabri as a *success*. His arguments for the success-claim was at the conference supported by experiences after a repetition at the start of Grade 9 in August 2006, more than half a year after their teaching period with Cabri (see Appendix 8xxix, p. 357). The test revealed good achievements both with Cabri and compasses. He also referred to students' answers in the mentioned survey (see Section 6.1.2,

p. 205).

When the teachers talked about students' achievements with Cabri, they also several times considered students' *working efforts* and that their students liked to work with Cabri. Already after a few of their lessons with Cabri, Frode reported that his students *loved* to work with Cabri (see Appendix 8xxx, p. 357). During LCM Workshop 11, approximately one month after their teaching period with Cabri came to an end, Frode and Jakob referred with pleasure to the *great efforts* among their students in Cabri-lessons (see Episode 5 below). They also in this episode referred to achievements in tests this time expressing satisfaction with the "unruly boys" who "achieved good scores on the Cabri-test":

Ut	Who	What is said (translation)	What is said (original)
120	Jakob	Yes I think this is something they have experienced as a nice thing to do and	Ja jeg tror det liksom er noe de synes har vært veldig ålreit aktivitet og
121	Frode	[Yes]	[ja]
122	Jakob	what I have seen was very big [effort]	det jeg har registrert veldig høy [aktivitet]
123	Some	[Yes]	[ja]
124	Aud	[Mm]	[Mm]
125	Jakob	in the lessons. There has been little life on the fat of the land, there have been much efforts	i timene. Det har vært lite sånn slaraffen altså det har vært det har vært jobbing altså.
126	Otto	Mm	Mm
127	Frode	Yes what was fun was when I ran a test on compasses and on Cabri. Same types of tasks. And the unruly boys achieved good scores on the Cabri-test.	Ja det som var gøy var at jeg kjørte test på de med passer og linjal og på Cabri. Samme typen oppgaver. Der de rampete gutte-ne har scoret bra på Cabritesten.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 5

Also Harald and Gunnar at Grade 9 expressed such experiences from their classes, but argued that some of their students, usually *achieving well* in mathematics, questioned *why* they had to use Cabri. Altogether this could indicate that use of Cabri motivated the students who usually did not succeed so well in mathematics and behaved a bit "unruly". On the contrary, some of the students who usually succeeded in mathematics seemed to experience the use of Cabri as provoking insecurity concerning a similar success in Cabri.

Although Jakob and Frode considered their teaching with Cabri as being successful resulting in improved achievements on tests, students' *weak background* and problems with *inaccurate use* of the tool were often mentioned. In the end of Cabri-use interview in March, Jakob considered what their students were able to achieve with Cabri referring to the Cabri-test in February (see Appendix 5c) already discussed in Section 6.1.2 and mentioned earlier in this subsection. Although the teachers in other sessions emphasised good achievements in tests (see p. 239), during the interview (see Episode 11 below) Frode argued that students' hand-ins from the test informed them that many of their students "did not handle the tool". Students often made constructions "*appearing correct*", but the dynamic dragging-function revealed that they had not constructed at all. When I considered their focuses in orchestration of Cabri-teaching in Section 6.1.3, *development of successful techniques* in Cabri was one of their two main focuses which the teachers often expressed as accurate use of Cabri:

Ut	Who	What is said (translation)	What is said (original)
275	Frode	And what we saw from their tests was that many of them were able to draw and construct, but they did not handle the tool in such a way it	Og det så vi på på prøvene som de gjorde at mange fikk til å lage og konstruere men de hånd-terte ikke verktøyet slik at på en måte altså den
276	Frode	[the]	[det]
277	Some	[Mm]	[Mm]
278	Frode	correct solution, it looked correct but if you	korrekte svaret, det så riktig ut men hvis du
279	Frode	[checked]	[testet]
280	Harald	[Mm]	[Mm]
281	Jakob	the figure and dragged the lines it showed that it was wrong.	figuren og dro i de linjene så ble det feil da.
282	Harald	Yes	Ja

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 11

In Episode 6 from ICTML Workshop 7 (see Appendix 8xxv, p. 355), Jakob expressed some surprise concerning his students' use of unsuccessful techniques in a perpendicular construction. Jakob used the teaching package (see Section 6.1.1) in most of the lessons, and his expressed surprise could indicate that he believed the package gave the necessary instruction in order to assist students' development of successful techniques in Cabri. In Section 6.1.1, I sketched the content of Worksheet 3 in the teaching package where constructions of perpendiculars were in focus. However, the technique Jakob described in Episode 6 is not addressed in detail in the worksheet although the construction of perpendicular is described. In addition, my own observations from the computer lab confirm that the students rarely seemed to read the part covering instructions to the theme of the worksheets. I also observed that Jakob and Frode typically instructed their students to work with the tasks in the worksheets, but I never overheard them urging students to read the rest of the worksheet. In sum, students' lack of being stimulated to read instructions in the teaching package, which in addition sometime had imprecise description of techniques, could explain why many of the students had problems to *use Cabri accurately* as Frode and Jakob typically expressed.

Above I have referred to a number of sessions were the teachers expressed an overall positive experience of students' achievements with Cabri. Although the teachers expressed some concerns about students' inaccurate use of Cabri in a test and in teaching, findings indicate that students' achieved well in tests, liked and put great efforts into their work with Cabri. The teaching package included instructions for accomplishing construction, but a combination of students' lack of reading the instructions carefully and teachers' lack of emphasising the instructions in the package seemed to have provoked a need for interventions from the teachers during students' use of Cabri.

6.1.6 Summary

In Section 6.1 Jakob and Frode's orchestrations in their Cabri-teaching has been considered. I have presented analytical findings related to the four questions phrased in the introduction to Chapter 6 (see p. 191):

a) Within what kinds of *arrangements* did the teachers use Cabri?
b) What kinds of *elements* in Cabri were in focus during the teaching?
c) What characterised teachers' *orchestrations* within their focuses and arrangements for use of Cabri?
d) What did the teachers comment on when they talked about their Cabri-teaching?

In Sections 6.1.1 and 6.1.2, teachers' use of a teaching package and their co-ordinated use of Cabri and compasses were revealed as two of their main *arrangements* for use of Cabri. In fact, to consider teaching with compasses and Cabri in such close relation, as an arrangement for use of Cabri, is in fact something I have *not* experienced being emphasised in previous research.

In Section 6.1.3 two main *elements* or focuses in teachers' orchestrations were emphasised: Students' development of successful techniques as the first and affordances and utilisation of affordances in Cabri as the second. When I characterised teachers' *orchestrations* in Section 6.1.4 emphasising the role of teachers' teaching operations and style of teaching, their focuses and arrangements for use of Cabri were evident. In Section 6.1.5 the same elements were expressed as crucial by the teachers when they *commented* on their teaching and students' achievements with Cabri. Findings in Section 6.1.5 indicate that Jakob and Frode experienced their use of the teaching package as creating little inquiry in their teaching. They also, in most of the sessions, argued that students should develop successful techniques in Cabri and learn to utilise the affordances in Cabri preferably before they could work with more investigative and inquiry oriented tasks. This latter finding is similar to what

Monaghan (2004) found when observing teachers practice in technology lessons where he argued that the teachers worked hard "to ensure that technical difficulties did not prevent students attending to the task." (p. 344). Overall, the different subsections in Section 6.1 give a coherent picture of the two mentioned elements (see Section 6.1.3) energising teachers' orchestrations with Cabri. This also indicates that these two elements worked as goals for their actions which are discussed in Section 6.3.2.

Overall, Jakob and Frode's orchestrations of Cabri-use did not differ much. Their arrangements were similar although Jakob mainly let his students' work in pairs and Frode's students worked alone. Jakob and Frode used the same teaching package and co-ordinated use of the two tools. The latter was observed many times such as when the teachers referred to lessons with compasses in Cabri-lessons, to techniques to be used in Cabri during their lessons with compasses and when the teachers commented that students constructed in a Cabri way with compasses. The two elements, focuses on students' development of successful techniques and utilising affordances, in particular the dynamic dragging-function, were also similar.

The accomplished orchestrations of lessons did differ a bit although many of the same teaching operations were observed. Pointing and moving the finger to the screen and sometimes taking over the possession of the computer mouse were typical teaching operations when assisting students in their work while more general teaching operations such as repetion and rephrasing of students comments and enthusiasm were utilised as teaching operations in their plenaries. Frode in general conducted more teacher-led plenaries than Jakob in accordance with his teaching style in other mathematics lessons. Based on the observed lessons with Cabri and compasses, I argued in Section 6.1.4 that Frode's plenaries in Cabri-lessons seemed to be briefer and with fewer questions than in his lessons with compasses. I did not observe such a tendency in Jakob's style of teaching. Both the teachers had a style of teaching' which I have denoted as being *supportive* and *step by step* based (see Section 6.1.4, p. 219) where *interventions* from the teachers either was directed to individual students, small groups or in plenary if several students had similar problems. In Section 6.1.5 I referred to an episode in one of the workshops in the LCM project where Jakob and Frode argued for use of plenaries as being time effective orchestration when such a problem occurred (see p. 233). Time as a key issue has also been emphasised in Chapter 5 and will be discussed further in Section 6.3.

In Sections 6.1.2 and 6.1.5, findings indicate that Jakob and Frode overall interpreted their co-ordinated use of Cabri and compasses as being successful in order to fulfil goals in the curriculum. Their students liked to work with Cabri and although their students had problems in using the tool, students' achievements were reported as having a good longitudinal effect. Frode's students were able to accomplish emphasised constructions with Cabri more than half a year after their first teaching with Cabri. Beside *success,* terms like *positive effect*, *great efforts*, they *loved* it and *good results* by the unruly boys were expressed to describe students' work with Cabri.

6.2 Trude's orchestration of Cabri-use

In Section 6.1 I have presented findings characterising Jakob and Frode use of Cabri and how they experienced their teaching with Cabri. Trude worked within another school, Fjellet, and used Cabri quite differently compared to Jakob and Frode. The analysis in this section (6.2) gives analytical findings concerning Trude use of Cabri and how she experienced her teaching.

In the introduction to Chapter 6 (see page 191), I listed the four questions below which guide the analysis and the structure of both this section and Section 6.1:

a) Within what kinds of *arrangements* did the teachers use Cabri?
b) What kinds of *elements* in Cabri were in focus during the teaching?
c) What characterised teachers' *orchestrations* within their focuses and arrangements for use of Cabri?
d) What did the teachers comment on when they talked about their Cabri-teaching?

Based on analytical findings in Section 6.2.1, I argue that a first characterisation of Trude's arrangement for use of Cabri was based on *accomplished teaching with compasses some distance in time from use of Cabri*. In Section 6.2.2 I argue that a second characterisation of her arrangement was based on how she organised her lessons. Her teaching with Cabri occurred in double-lessons in the classroom where half of her class worked with Cabri and the other half with other tasks in their textbooks. The two halves switched in the middle of her double-lessons. The tasks students' were supposed to work with were offered on a flip-chart, followed by a working phase and brief oral summary.

Findings in Section 6.2.3 indicate that Trude in a first step, what I denote as Step 1, directed her attention to some of her students and assisted them in their development of techniques and utilising affordances in Cabri. What she wanted to achieve was a next step, denoted Step 2, to challenge her students' to *share their achievements with other students emphasising collaborative and investigative efforts* with Cabri. Thus these were important focuses in Trude's orchestration of Cabri-teaching. The section also contains findings related to how Trude experienced and gave comments to her Cabri-teaching. She emphasised *students' efforts* and the *personal triumph* with daring to teach Cabri.

The nature of Trude's orchestrations of Cabri-use is emphasised in Section 6.2.4. Similar to Section 6.1.4 for Frode and Jakob, analytical findings illuminate a characterisation of Trude's *teaching style* in Cabri-lessons and the role of *teaching operations* in her orchestration. Her teaching style in Cabri-lessons is denoted as an *encouraging teaching style* where she utilised *enthusiastically speaking* and *pointing* with finger at students' screen as her main teaching operations.

Similar to one of the focuses in Section 6.1.5, in Section 6.2.5 I discuss the *role of inquiry* in Trude's Cabri-teaching and Trude's *interpretation of inquiry*. Inquiry was a term discussed throughout the developmental projects and teachers' emphasis on inquiry a desired outcome from teachers' participation in the projects.

In LCM Workshop 10 on the 11th of January 2006, Trude reported from her first ever use of Cabri in teaching five days earlier (see Episode 1, p. 137). Later in the workshop, she also exposed her further plans for using Cabri in double-lessons almost every Friday until Easter 2006 (see Appendix 8xxxi, p. 358). However, a number of reasons led to a decrease in the number of Cabri-lessons held by Trude. She ended up using Cabri in total six Fridays in January, February and March before she had a break from her teaching-job for the rest of the school year. The analysis of Trude's teaching with Cabri is based on observations of two of her Cabri-lessons, her second and fifth out of a total of six double-lessons with Cabri. Her experience from working with Cabri is supported by analysis of data from conversations with her quickly after the double-lessons, and contributions from Trude in four workshops in the developmental projects.

In the coming sub-sections a total of eight events are considered. An overview of seven of the events is presented below in Table 6.5 where, as for the earlier tables in this chapter, the numbers refer to the total list of events in the case study provided in the overview in Appendix 1. The event on the 6th of January was not observed by me or other didacticians since we were not informed about her lesson, but the event has been included in the table since Trude referred to the content and her experience of the lesson in several sessions (included Events 16, 21 and 22).

Table 6.5: List of events considered in the subsections to this section (6.2)

Event	Date	Type of sessions
	06.01.2006	Cabri: Line, points and circles
16	11.01.2006	LCM Workshop 10 at UiA
21	18.01.2006	ICTML Workshop 7 at UiA
22	20.01.2006	Cabri: Construction of triangles (the main theme)
23	20.01.2006	Conversation with Trude a few minutes after her Cabri-lesson (see Event 22)
30	22.02.2006	LCM Workshop 11 at UiA
32	10.03.2006	Cabri: Symmetry tasks and drawing
33	10.03.2006	Two brief conversations within and few minutes after her Cabri-lesson (see Event 31)

6.2.1 Use of Cabri in some distance from use of compasses

Trude's double-lessons with Cabri occurred in the classroom some weeks after her teaching with compasses in geometry. Jakob and Frode used the two tools often in consecutive lesson and in a co-ordinated way as argued in Section 6.1.2, while Trude's use of Cabri was not so co-ordinated in time. She orchestrated work with themes in geometry with *compasses first and afterwards practicing related themes using Cabri*. Trude exploited students' background from use of compasses as an important *criterion* for students' work with Cabri. This is evident from the final part of her 20th January lesson. She had a two minutes summary where she emphasised how things done *earlier with compasses* would be worked on with Cabri in the coming weeks. Trude also argued that if students were good in using compasses it would be easier with Cabri:

Ut	Who	What is said (translation)	What is said (original)
357	Trude	Hereafter you will see that we do more and more things we have done in the book (*talks about Cabri while "the book" refers to work with compasses*). The more capable you are with compasses and ruler you will manage quicker here (*Cabri*). We learn from each other. It was fun watching your collaboration today.	Dere vil se at vi utover gjør flere og flere av tingene vi har gjort tidligere i boka (*snakker om Cabri ens "Boka" refererer til bruk av passer*). Jo bedre du er med passer og linjal jo raskere får du det til her (*Cabri*). Vi lærer av hverandre. Det som er gøy i dag var og se hvordan dere hjalp hverandre.

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video, Episode 6

In this episode, Trude also argued that if students are good in using compasses it will be easier with Cabri. This utterance illustrates an important element about progression in Trude's geometry teaching: Work with themes in geometry with compasses first and afterwards practicing related themes using Cabri. Thus, use of Cabri with some distance in time from use of compasses is a *first* characterisation of Trude's arrangement.

6.2.2 Use of Cabri guided by tasks offered on a flip-chart

A *second* characterisation of her arrangement for use of Cabri was related to how she organised her double-lessons with Cabri. I first consider her minimal use of instruction material in contrast to Jakob and Frode’s use of a teaching package in most of their Cabri-lessons (see Section 6.1.1). Trude did not use any teaching package except in one of her latest double-lessons. The tasks Trude’s students’ were expected to work with in Cabri were presented on a flip-chart. Trude formulated the tasks more openly and orally emphasised investigation and collaboration including utilisation of dynamic affordances. The tasks could have been addressed with compasses too, but not in the dynamic way possible in Cabri. In order to describe her orchestration of students’ work with Cabri (see Section 6.2.4) and what were in focus in her teaching (see Section 6.2.3), the tasks which guided students’ work are worth attention. Figure 6.8 contains a copy of what Trude had written on the flip-chart ahead of the Cabri-lesson on the 20th of January 2006 where construction of triangles was the main theme. As indicated in Figure 6.8, Trude used drawings of triangles instead of writing triangle as a word.

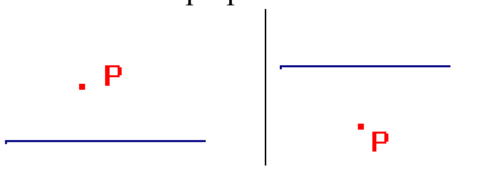
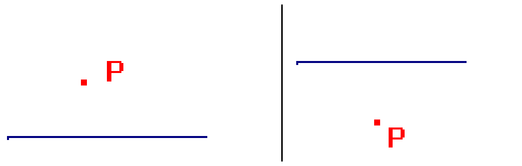
Copy of flip-chart (translation)	**Copy of flip-chart (original language)**
1. Equilateral △	1. Likesidet △
- with symmetry axis	- m/symmetriakser
- more ways to make △	- flere måter å lage △
2. Construct an isosceles △	2. Konstruer likebeint △
- Find the symmetry axis	- finne symmetriakser
3. Construct perpendicular lines:	3. Konstruer normaler:
	
4. Make angles, and calculate angles	4. Lage vinkler, sette på mål
5. Construct parallel lines	5. Konstruere parallelle linjer
6. Stars, several, different?	6. Stjerner, flere, forskjellige?

Figure 6.8: Copy of flip-chart used by Trude on the 20th of January 2006

As mentioned in the introduction to Section 6.2, Trude’s double-lessons with Cabri occurred in her classroom where half of all the students worked with tasks in textbooks and half with Cabri using laptops and these two groups switched in the middle of the double-lesson. The students who used Cabri were placed in one of the corner of the room. The textbook tasks were not related to the same geometrical content worked on with Cabri. The overall arrangement of the observed double-lessons was the following:

- A brief 2-4 minutes oral review and introduction to the double-lesson for all the students in plenary.

- Trude accomplished a brief 1-2 minutes introduction to the students' who worked with Cabri in the first half of the lesson. The tasks were presented on a flip-chart.
- A 35 minutes working phase with Cabri and the textbook tasks for each of the groups ended by the midway break.
- The second part of the double-lesson started with 1-2 minutes introduction for the students who were supposed to work with Cabri in that part of the lesson. It was followed by a 35 minutes working phase with Cabri and the textbook tasks for each of the groups
- A 3-5 minutes oral summary in plenary for all students.

6.2.3 Emphasis on students' collaboration and investigation

This section considers what Trude seemed to have wanted to achieve with her Cabri-teaching. This is done by considering what she emphasised when she talked about her Cabri-use in workshops and conversations. I also consider what were in focus throughout her orchestration in the Cabri-lessons especially paying attention to what she emphasised in her oral introductions and summaries at the end of her double-lessons.

As a first step in Trude's orchestration of students' Cabri-use, she had a focus on *assisting* single students in their *investigation* of *techniques* in Cabri. The three episodes considered below are from her double-lesson on the 20th of January. I characterise how Trude orchestrated by assisting one of her students, Emil, in his work with Task 1 on the flip-chart (see Figure 6.8 above). I did not observe that Emil gave any signal indicating need of assistance, but Trude came to his place and looked at his screen for a short while. Emil had made a line and two equally big circles intersecting each other as illustrated in Figure 6.9:

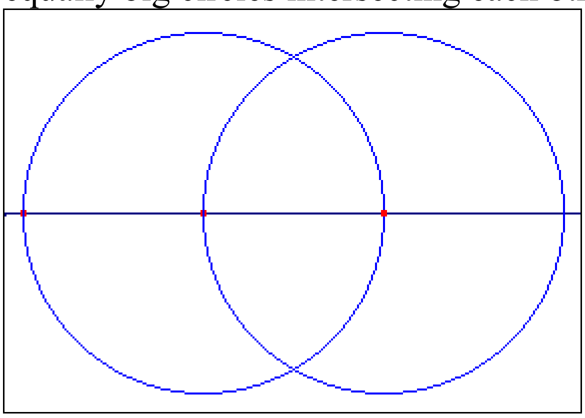


Figure 6.9: Copy of Emil's screen before Trude orchestrated his work with Cabri

Trude started off by assisting Emil in drawing line segments from the centres of the circles to the intersection point above the line. This is illustrated below in Episode 1 where it is *technique* in Cabri that is being emphasised:

Ut	Who	What is said (translation)	What is said (original)
123	Trude	Click [there]	Trykk [der]
124	Emil	[Yes]	[Ja]
125	Trude	in the middle and then you put the pencil in that point there (…)	midt på og så sett sett setter du blyanten i det punktet der (…).
126	Emil	Yes yes	Ja ja
127	Trude	Yes great	Ja flott
128	Emil	(*not audible*)	(*ikke hørbart*)
129	Trude	You master it!	Du kan det!

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video, Episode 1

Few seconds later, Trude asked Emil about what he had achieved, the name of the figure and challenged him to "find the symmetry axis" (see Appendix 8xxxii, p. 358). This kind of comment indicates that Trude wanted Emil to *investigate techniques* in Cabri. Trude made no comment to *why* Emil had started with the two circles, which was crucial for the successful solution of this task. After some more seconds, Trude orchestrated by assisting Emil in making midpoints on each lateral of the triangle (see Episode 3 below) again emphasising *techniques* with Cabri:

Ut	Who	What is said (translation)	What is said (original)
155	Trude	Look, look at the midpoint there	Se se midtpunkt se på den.
156	Emil	Yes	Ja
157	Trude	That one yes, a bit too long. If you then mark the point there	Den ja litt for langt. Hvis du da merker det punktet der.
158	Emil	That one?	Den der?
159	Trude	And there. The midpoint (*refers to the option in the menu bar in Cabri*). Click there, yes. And there and so there. There you got it. If you now try that one there and down there (*Trude pointed with her finger to the menu bar*). Then you have a symmetry axis. And then you repeat it on that one. You find the midpoint	Og der. Midtpunktet der (*referer til valget i menylinja i Cabri*). Trykk der ja. Og så der og så der. Der fikk du den. Hvis du nå prøver den derfra og ned der (*fingeren peker på menylinja*). Da har du en symmetriakse. Og så gjør du sånn på den og på den. Du finner midtpunktet.

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video, Episode 3

In this episode, Trude orchestrated Emil in making midpoints and afterwards in drawing segments between corners and opposite midpoints which is the symmetry axis for the equilateral triangle. The midpoints were made by choosing "Midpoint" on the menu bar in Cabri.

Although Trude spent time on assisting single students in their investigation of techniques, I argue that analytical findings in this section (6.2.3) indicate that what she really wanted to experience was another step: challenging her students' to *share their achievements with other students emphasising collaborative and investigative efforts* with Cabri.

To substantiate this claim, I first consider the continuation of Trude's assisting of Emil's work. Two minutes after the start of the intervention by Trude into Emil's work, he had succeeded in making an equilateral triangle with symmetry axis. In Episode 4, immediately after Emil had succeeded in solving Task 1, she *asked* Emil to assist Jarl who was sitting next to him.

Ut	Who	What is said (translation)	What is said (original)
163	Trude	Yes. Now you can help Jarl so he can manage it and you must do it one more time afterwards.	Ja. Nå skal du hjelpe Jarl så han får det til og så skal du gjør det en gang til etterpå.
164	Emil	(not audible)	(*ikke hørbart*)
165	Trude	Bravo. Two, two symmetry axis. And then one more.	Bravo. To to symmetriakser. Og så en til.
166	Emil	(*not audible*)	(*ikke hørbart*)
167	Trude	You are so clever. Do you see it? Fun!	Så flink du er. Ser du det? Moro!

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video, Episode 4

After Episode 4, Trude left Emil and the student next to started looking at Emil's screen and Emil pointed with his finger and made a brief comment to the student. As indicated in the description of Trude's arrangement for use of Cabri (see Section 6.2.2), Trude ended the double-lesson with a oral plenary standing upfront with the blackboard. She expressed appreciation of students' well purposed *collaborative* work and success in making equilateral triangles. She asked her students for reason for this success, and one of her students replied that they now were able to manage it. Trude then *rephrased* the question emphasising *why* they now manage it. Episode 5 contains Dina's response to this question where she argued that Lisa had *learnt* her to manage it. Dina used the word learnt in a way which students often in Norway use the word covering the outcome of being taught and indicate a behaviour which Trude had stimulated in her orchestration of Cabri-use: Students *assisting* each other or what I have denoted as *collaborative work*. In response to Dina's contribution, Trude supplied her question once more in utterance 321 challenging the students to consider critically why the construction worked:

Ut	Who	What is said (translation)	What is said (original)
320	Dina	Lisa learnt me it.	Lisa lærte meg.
321	Trude	Lisa learnt you it? What do you need to know before starting to work with this? In order to manage it with Cabri, what did you have to know?	Lisa lærte deg det? Hva må du kunne før du skulle begynne å jobbe med det her? For å få det til på på Cabri hva måtte du vite da for noe?

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video, Episode 5

Trude did not get any answers from the students on this question, but her repeated emphasis on *students' collaboration and investigation* indicates that it was something she wanted to achieve. To substantiate that this emphasis was crucial for Trude throughout her Cabri-teaching I offer analytical findings based on her comments from her first ever Cabri-lesson and a later double-lesson in March.

In LCM Workshop 10, Trude reported from her first Cabri-lesson five days earlier and two weeks ahead of the double-lesson considered above. Trude argued that she had introduced *point*, *line* and *circles* for the students, and that they gradually managed to make *isosceles* triangles. In Episode 4 in the ICTML workshop one week later, Trude reported from the same lesson as in LCM Workshop 10. Trude emphasised how the achievement by the different students in the lesson had *diverged* from the others and stimulated *comparison* and *verification* of their solutions utilising the affordance of *measuring* lengths in Cabri:

Ut	Who	What is said (translation)	What is said (original)
176	Trude	… And they managed it after almost one hour, then they had solved it and found; now we have it. And then, when one student had succeeded, found this equilateral triangle I observed how the others looked at his and said, oh yes mine is a bit (…) and then they found the possibility of measuring to check the lengths. These were such a joy in the classroom; and the teacher was the happiest one	… Og de klarte det sånn etter nesten en time så hadde de løst og funnet nå har vi det. Og da hvor når når en da hadde fått løst den funnet denne likesidede trekanten hvordan de andre rett og slett stakk bort og så å ja min er litt (…) og så fant de ut at de kunne måle og sjekke lengdene. Det var altså sånn en glede i klasserommet; og læreren var vel den gladeste.
177	Several	(*Laughter*)	(*Latter*)
178	Trude	And then we exchanged and told them to restart and make it on their own. …	Og så byttet vi og jeg sa at nå må dere gjøre alt blankt og så må du gjøre det på egenhånd. …

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 3

Trude emphasised with great enthusiasm students' efforts. In Episodes 4 and 5 (in Appendix 8xxxiii, p. 358 and Appendix 8xxxiv, p. 359) from LCM Workshop 10, one week earlier, Trude reported that students' efforts had resulted in *excellent learning.* Her students had, almost without her assistance, investigated the tool, shared ideas and checked their solutions by utilising the measuring affordance in Cabri. In Episode 3 above, Trude also expressed great joy with her experience from her Cabri-lesson. To dare to use Cabri in teaching was in Chapter 5 illuminated as Trude's main issue when considering implementation of Cabri. Her expressed joy, emphasising that she was the happiest one, indicates her *personal triumph* with daring to teach Cabri.

Observation during Trude's Cabri- lesson on the 10th of March indicated a similar focus in her orchestration of students' work. In a conversation immediately after this double-lesson, Trude commented on students' work the same day. Episode 2 below illustrates how Trude *reacted* to some of her students who tried to *utilise an affordance in Cabri*, the possibility to draw regular polygons instead of making a general triangle as they were expected to in the task. In the observed double-lesson, she did not correct their use of the menu option in Cabri, but instead challenged them as indicated in the conversation below. In utterance 113 I commented to Trude that she asked them to consider other types of triangles than equilateral triangles. Trude responded arguing that this *way of working* and *questioning* were how she wanted to see the work in her class:

Ut	Who	What is said (translation)	What is said (original)
106	Trude	Did you watch the boys who sat over there, in the corner? They grasped both circumscribed and inscribed circle. It was no problem. Because they found the functions (*refers to menu options in Cabri*). While the first one who started on the task, Asle, he found it, he applied diagonals	Du så de guttene som satt der borte i kroken? Det tok det med omskreven sirkel og innskrevne sirkel. Det var det enkleste av verden. For de fant funksjonene (*referer til menyvalg i Cabri*). Mens han som begynte først på det, han Asle. Han fant det jo ut, han tok diagonalene
107	Ingvald	[yes, the perpendicular bisector]	[ja midtnormalen]
108	Trude	Yes, the perpendicular bisectors	Ja midtnormalene
109	Ingvald	on the laterals. But he too had started with regular triangle and then you have that intersection point	på sidene. Men han hadde vel også begynt med regulær trekant og da får du jo det skjæringspunktet
110	Trude	Yes, they were lucky there	Ja det var jo heldig for de
111	Ingvald	Yes, but it did not matter so much, because I think it potentially could spoil the task but it did not	Ja, men det gjorde, jo jeg tenker det kan jo ødelegge oppgavene men det gjorde jo ikke det
112	Trude	No	Nei
113	Ingvald	and you asked them quickly concerning other types of triangles	og nå spurte jo du veldig fort også om det gjaldt for andre trekanter enn
114	Trude	Yes, and I do think this is really the way I want us to work.	Ja, og jeg tenker at det er jo egentlig sånn jeg vil vi skal jobbe.

Event 33, Mar 10th 2006, Fjellet, Trude, Cabri, Conversation, Audio, Episode 2

The episode above also exemplifies a *difference* between Trude and Jakob and Frode. Trude did not seem to find students' utilisation of menu options like perpendicular and parallel as a problem while Jakob and Frode more strictly emphasised the importance of constructions of the same things.

Analytical findings in this section where data from a workshop, conversations and classroom visits have been considered indicate a consistency in what Trude emphasised in her Cabri-teaching. Her summing up at the end of the 20th of January illustrates this There Trude talked for about 30 seconds quite enthusiastically about students' use of Cabri in her first ever lesson two weeks earlier. She expressed big *pleasure* of observing the great efforts by the students when they worked together with Cabri in what I have denoted as collaborative investigative efforts based on a first investigation of techniques. Consequently, she reported in a similar manner as in the workshop from students' efforts with Cabri. A similar emphasis is evident when I describe Trude's teaching style below.

6.2.4 Style of teaching and the role of teaching operations

This section reveals analytical findings concerning the *nature* of Trude's orchestration in the Cabri-lesson related to her emphasis on students' collaboration and investigation illuminated in the previous section. Similar to the analysis of Jakob and Frode's teaching in Section 6.1.4, findings in this section illustrate a number of *teaching operations* exploited by Trude such as *pointing* with finger and *enthusiasm* in her speaking. Based on findings I argue that Trude had an *encouraging style of teaching* in her Cabri-lessons.

Trude's style of teaching in Cabri-lessons

When I considered Jakob and Frode's styles of teaching in Cabri-lessons, I quoted research papers focusing on teachers' style of teaching (see Section 6.1.4, p. 219). The analysis indicated a relatively stable style of teaching when using either compasses or Cabri but a minor difference in consistency between Jakob and Frode. Since Trude's teaching with compasses had come to an end when I started to observe her Cabri-teaching, a similar study of her teaching with compasses was impossible. Thus, this section gives analytical findings of Trude's teaching style in Cabri-lessons. In Chapter 7 I briefly indicate the generality of this teaching style.

In Section 6.2.2 I indicated the overall arrangement of Trude's Cabri-lessons by presenting a list (see p. 247). This arrangement gave a frame for Trude's orchestration of students' Cabri-use where most of the time was reserved for students' collaborative and investigative efforts with Cabri after first emphasising students' techniques with Cabri (see Section 6.2.3). This latter key finding from Section 6.2.3 is illustrated in Figure 6.10 below:

Step 1
Students' were assisted by Trude to investigate techniques with Cabri

→

Step 2
The students were challenged by Trude "to share their achievements with other students emphasising collaborative and investigative efforts with Cabri" (see Section 6.2.3, p.253)

Figure 6.10: A two step focus in Trude's Cabri-orchestration of students' work

Before considering Step 1 and Step 2 as indicated in Figure 6.10, I briefly describe the nature of her plenaries. As indicated in the list, Trude never presented explicitly in plenary how the students could use Cabri to investigate the tasks. Instead the plenaries were oral at the start and end of the double-lesson, and with a brief oral introduction supported by a flip-chart with the tasks to the group of students who were about starting their work with Cabri. In ICTML Workshop 7 she indicated her presentation of the tasks as the starting point:

Ut	Who	What is said (translation)	What is said (original)
176	Trude	…. And then I said there is three buttons which you shall use today: line, point and circle. Now you are allowed to play and practice and try to make an isosceles, equilateral triangle. And they started off and it was such fun to watch them. And I continued working with the rest of the class all in the same room. …	… Og så sa jeg det er tre taster dere skal bruke i dag: Linje, punkt og sirkel. Nå skal dere få lov til å leke litt og øve dere og så skal dere altså lage en likebenet, likesidet trekant. Og satte i gang og det var så moro og se på dem. Og jeg holdt på å undervise resten av klassen og alt på samme rom. …

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 2

Her comment supports my observation that she did not give any *detailed descriptions* concerning how to use Cabri at this initial stage. In her double-lesson on the 20th of January, Trude quickly read through line for line the six tasks on the flip-chart (see Figure 6.8, p. 247). She also repeated her earlier statement from the introduction concerning collaboration and possibility of having some further help by her and myself.

In the rest of this section I consider Trude's teaching style when orchestrating students during their working phase with Cabri with the two-pieced focus which I denote as Step 1 and Step 2 in her orchestration of students' work (see Figure 6.10 above). In Section 6.2.3 I presented a dialogue between Trude and Emil. Within a couple of minutes Emil was able to use techniques which worked in Cabri (see Episode 1-3, p. 249-249). In this Step 1 orchestration of Emil, she very specifically instructed Emil with comments such as "then you put the pencil in that point there" (Episode 1) and "mark the point there" (Episode 3). Afterwards Emil was asked to share and discuss his work with others (see Episode 4, p.

250) as a start of Step 2 in her orchestration of students' work. In a conversation between Trude and me immediately after the lesson, Trude's comments indicate that the observed orchestration by assisting Emil was a deliberate choice. He was one of the "cleverest" (see utterance 49) boys and she wanted to assist him in order for him to be able to assist other students:

Ut	Who	What is said (translation)	What is said (original)
45	Trude	You did notice the boys who sat there?	Du så, de guttene som satt der.
46	Ingvald	[Yes]	[Ja]
47	Trude	They are clever	De er flinke
48	Ingvald	[Yes]	[Ja]
49	Trude	They are the cleverest I have	De flinkeste jeg har
50	Ingvald	Yes	Ja
51	Trude	So what I often do its to let them work with the tasks first	Så det jeg ofte har gjort er at de jobber med oppgavene først
52	Ingvald	[Mm]	[Mm]
53	Trude	in such a way that they can help the others if they are stuck and I am busy with other students in the classroom and do not have the possibility to help them. So I tell them to drop in to the others (*she means to help the others*)	slik at de etterpå kan hjelpe de andre hvis de står fast og jeg er opptatt på andre siden av klasserommet og ikke kan hjelpe de andre. Så sier jeg, stikk bort til han (*mener å hjelpe de andre*)

Event 23, Jan 20th 2006, Fjellet, Trude, Cabri, Conversation, Audio, Episode 1

Trude started off by assisting some of her cleverest students individually offering instructions emphasising techniques in Cabri similar to many of the observed *plenary* orchestrations of students' work by Jakob and Frode. When these students succeed with the tasks, she asked them to assist other students particularly that her cleverest students assisted students who struggled more. Half a minute later, Trude argued for her orchestration of students' work emphasising the importance of allowing students to help each other, *collaboration* among students. Trude also added for her approach by commenting on the *impossibility* for her to assist everyone:

Ut	Who	What is said (translation)	What is said (original)
63	Trude	Because I think some of the most important with education is that I allow them to help each other	For jeg tenker noe av det viktigste med opplæringen er at de får lov til å hjelpe hverandre.
64	Ingvald	Mm	Mm
65	Trude	Because I as the teacher have no chance to help them all.	for jeg som lærer har ikke sjans til å hjelpe alle.

Event 23, Jan 20th 2006, Fjellet, Trude, Cabri, Conversation, Audio, Episode 2

The kind of teaching style Trude argued for in these episodes seems similar to what she expressed as leading to *excellent learning* in the LCM workshop eleven days earlier (see Appendix 8xxxiii, p. 358). I denote her style as an *encouraging teaching style* where she wanted to support students' collaboration and investigation of Cabri. Her teaching style, which I argue emphasised orchestration of a Step 1 and a Step 2 in students' working phase with Cabri, is further outlined on the coming page where her teaching operations are discussed.

Trude's encouraging teaching style was indeed also typical in her plenary introductions to the double-lessons, like on the 20th of January where she challenged her students to *share* and discuss their solutions with each other if they succeeded. Her challenging approach was also evident when she said: "I do not know exactly how to solve all the tasks with Cabri" indicating that she interpreted herself as a learner as well. This comment could indicate a *deliberate* choice as suggested so far in this subsection in accordance with her *encouraging teaching style*. However, I find support for three other kinds of supporting reasons for the observed teaching style:

1. As commented above, Trude argued that it would have been impossible for her to assist all her students so she wanted them to help each other.
2. Trude many times expressed a lack in *self-confidence* to her own capabilities with computer software like in LCM Workshop 10 in January 2006 where she claimed: " I am not very clever in this (*refers to Cabri*), far from good on it" (see utterance 27, p. 170). Thus, her encouraging teaching style where she wanted the students to work investigative and collaborative, with no plenaries where she demonstrated use of Cabri, could be influenced by or a result of this lack in self-confidence. Was her teaching style energised by a hope that her students would be able to assist each other, since she did not believe she would be able to assist them herself?
3. Was her teaching style provoked by didacticians suggesting her to teach in such a way? I find indications for this claim when Trude in a workshop session referred to "a kick in the back end" from didacticians (see utterance 176, p. 138).

Thus, Trude's teaching style seems to have been influenced by the developmental projects, where implementation of computer software and inquiry emphasising students collaboration and investigation had been suggested, her own limited background from use of computer software in teaching and a doubt whether she would be able to assist every student. Section 6.2.5 treats inquiry in Trude's Cabri-teaching. Although I only observed Cabri-lessons, the comments in this subsection might indicate that her teaching style in Cabri-lessons *not* were entirely typical for her style of teaching.

Trude's teaching operations in Cabri-lessons

In this subsection I present analytical findings concerning the role and nature of Trude's teaching operations based on observations of double-lessons with Cabri. I have earlier in the chapter, like in the introduction to the similar subsection with Jakob and Frode (see p. 224), referred to what I denote as teaching operations and that they were observable in Cabri-lessons through a teacher's instructions and questions.

Like for Jakob and Frode, findings indicate that a number of the teaching operations Trude used in her Cabri-teaching had a *general* nature. An example was when, in the summing up in plenary after the Cabri-lesson on the 20th of January, Trude utilised *rephrasing* of question (see p. 250). The main example of a teaching operation having a general nature was her use of *enthusiastic* words. In Episode 4 from the same double-lesson, Trude used words and expressions like "Bravo", "You are so clever" and "Fun" (see p. 250). This use of enthusiasm relates to her encouraging teaching style which earlier in the lesson was expressed as "Yes great" and "You master it!" (see p. 249).

Trude also utilised computer software related teaching operations. The main teaching operation I observed of this kind was pointing with her finger at students' computer screens and sometimes tracing her suggested computer mouse movement. An example is her orchestration of Emil's work (see Episode 1, p. 249) where Emil is asked to draw a line-segment by moving the mouse-pointer similar to the trace of her finger. Her pointing was often combined with reference to mathematical concepts like to midpoint in Episode 3 (see p. 249).

The same kind of teaching operations as for Trude were observed in Jakob and Frode's Cabri-teaching (see Section 6.1.4). As a difference, Jakob and Frode introduced the terms *fix*, *hook* and *glue* to support their orchestration of students' techniques in Cabri. I never overheard that Trude introduced such terms or similar terms.

6.2.5 Inquiry in Cabri-teaching

It is evident from analytical findings in Section 6.1 that Jakob and Frode did not consider their teaching with Cabri to have involved much inquiry. They argued for their non-emphasis on inquiry based on their use of a teaching package with tasks that did not promote inquiry, mainly individual work and that inquiry with use of Cabri preferable could come at a later phase with Cabri in teaching.

As already mentioned earlier, Jakob, Frode and Trude discussed whether their Cabri-teaching involved inquiry. In LCM Workshop 11, Trude argued why she experienced her teaching with Cabri *differently* from Jakob and Frode's teaching (see Appendix 8xxxv, p. 359) but still by her comments indicated that she did not consider her teaching to have involved inquiry. She mentioned her non-use of any teaching package and that she was just presenting the tasks supposed to be solved in collaboration, as two points to distinguish her teaching from Jakob and Frode's teaching. She used expressions like *enormous* working-effort and that her students were *totally crazy*, to describe students' work with Cabri. When Trude described her own teaching, she exemplified by referring to how she *challenged* her students to *investigate different types* of polygons. In her teaching, I observed repeated use of "What if" questions from Trude in addition to her use of positive enthusiastic words and challenge for collaborating. Thus, although Trude questioned whether she had succeeded in having inquiry implemented in her teaching, inquiry is noticeable from the mentioned characteristics in this paragraph.

6.2.6 Summary and further considerations

In the sub-sections to Section 6.2 I have presented analytical findings concerning Trude's orchestration of her Cabri-teaching. In Sections 6.2.1 and 6.2.2 her arrangement as part of her orchestration was revealed. Use of Cabri in some distance from her teaching with compasses and organising where the open formulated tasks on a flip-chart directed students work were two central arrangements.

In Sections 6.2.3 and 6.2.4 I presented analytical findings concerning her emphasis in teaching, style of teaching and teaching operations to indicate her orchestration of students' Cabri-use in teaching. Findings in Section 6.2.4 indicate that Trude had an encouraging teaching style in her Cabri-lessons. She utilised enthusiasm as well as pointing to the computer screens as her main teaching operations which combined seemed to support her emphasis on stimulating students' collaborative and investigative efforts with Cabri. The latter was in Figure 6.10 (see p. 254) illustrated as her Step 2 focus, while the Step 1 focus was on assisting students' investigation of techniques with Cabri. In conversations she emphasised that she particularly wanted to assist the "cleverest boys" in what I denote as her Step 1 in order for them to have something to share in Step 2. In the conversation after her 10th of March double-lesson, a comment from Trude indicates that the solution to rely on the "cleverest boys" could be a gender issue. She expressed her interpretation of a great achievement in her double-lesson by Leah, one of the girls in her class. Trude emphasised that it was particularly fun for that one of the girls had success with Cabri (see Appendix 8xxxvi, p. 360). However, it might also be a more non-gender reaction based on her experience that a number of boys in her class were the cleverest.

I have commented (see p. 256) that Trude never in plenary demonstrated use of Cabri. There I suggested that her style of teaching, which I have described as an *encouraging teaching style*, might be a choice highly grounded in her own lack of confidence in using Cabri. It could also, more in general, be related to her lack of confidence and experience in using technical equipment. This was emphasised by Trude in the conversation after her double-lesson with Cabri on the 20th of January (see Event 23). She mentioned that she did not order the video projector in advance of the double-lesson, and added that she was not able to use a video projector. Further, that she had been really worried about using Cabri but not as much as the first time she used it (one week earlier) because of her expressed lack of skills and teaching experience in using Cabri. These comments appear to be influenced by her lack of *self-confidence* with computer software expressed many times. Still two years after her first lessons with Cabri in January 2006, Trude commented "you know how bad I am in data" in an e-mail response indicating this lack in self-confidence. In the e-mail, Trude commented her teaching with Cabri in the new Grade 8 and 9 classes earlier the same month:

What is said (translation)	What is said (original)
Now you will be impressed because I last year ran a Cabri course at Grade 8 before I got sick. But now, in December and January 08, I have had Cabri courses here both at Grade 8 and 9, which I consider as good because you know how bad I am in data. …	Nå vil du bli imponert, for jeg kjørte Cabri-kurs med 8.klasse i fjor høst før jeg ble syk. Men nå ides og jan08 har jeg hatt cabri-kurs med både 8.klasse og 9.klasse her på huset, og det synes jeg er bra når du vet hvor dårlig jeg er i data. …

Event 43, Jan 17th 2008, Fjellet, Trude, e-mail responses, Audio, Episode 1

Although there could be different reasons why her orchestration of Cabri-use in teaching was the way it was, findings illustrate a teaching style, emphasis in teaching and teaching operations where students were encouraged to investigate and collaborate by Trude. Later, in Section 7.1.5, I conclude that her style of teaching could be described as being energised by a development of *inquiry as a way of being* with reference to how this expression has been used in research papers related to the LCM project (Jaworski, 2004a, 2007). There I also suggest consequences her role and emphasis in teaching had on students' work with Cabri.

6.3 Findings from analysis of teaching with Cabri

Sections 6.1 and 6.2 contain analytical findings of Jakob, Frode and Trude's orchestration of Cabri-use and was summarised in Sections 6.1.6 and 6.2.6. Their orchestrations have been characterised based on consideration of their arrangements for use of Cabri, emphasis in their Cabri-teaching and I have indicated teaching styles and teaching operations when using Cabri. I have also included analysis of data where teachers talk about their Cabri-teaching including teachers' interpretations of inquiry, the role of inquiry in their teaching and students' achievements with Cabri. A first major difference found was in the teachers' arrangement. Jakob and Frode used a teaching package in most of the Cabri-lessons while Trude just presented tasks with no description. The other main point of difference was in their emphasis. Jakob and Frode had an emphasis on students' *successful techniques*, *affordances* and in hand *utilisation* of *affordances* in Cabri while *investigation of techniques* just was a first step in Trude's emphasis. Her main focus was on students' *collaboration and investigation* of Cabri including *utilisation* of *affordances*.

Based on the findings from Sections 6.1 and 6.2, I start off Section 6.3.1 discussing the role of *teachers' interventions*. In Sections 6.3.2 and 6.3.3 I utilise the activity theory perspective elaborated in Chapter 3 in analysis of findings in this chapter. In these two sections I aim to illuminate teachers' *goals* for the *actions* and *operations* with Cabri and how Cabri evolved as a *cultural tool* in Jakob, Frode and Trude's classes. In Section 6.3.4, teachers' operations are considered further by analysis of teachers' *instrumental orchestrations* of students' use of Cabri utilising the instrumental approach.

6.3.1 Instances in teachers' interventions

Analysis in Sections 6.1 and 6.2 have illustrated that the three teachers intervened into students' work in Cabri differently. Goos et al. (2003, p. 86-87) refer to *four instances* of teacher *interventions* in a technological environment which was listed in the following way in Section 2.3.2 (see p. 50):

1. Directing students to explore the tasks
2. Emphasising use of technology to discuss the solutions of a task
3. Holding back information and stimulating collaboration among students
4. Emphasising plenary presentations from groups of students followed by critical discussions

In this paragraph I discuss and relate Jakob, Frode and Trude's orchestrations of Cabri-use, in particular what I have referred to as their emphasis in teaching and style of teaching, to the kinds of interventions suggested by Goos et al.

Jakob and Frode's support for students' work were typically in the form of instructions either in plenary or in conversations with each student or groups of students during their working phase. Jakob and Frode's interventions typically happened when I observed that their students used *techniques* in Cabri that they did not experience as successful in Cabri. If several students had similar problems, Jakob and Frode intervened in plenary presenting how to use Cabri accurately as the teachers stated it. The instructions had an emphasis on how to use a technique and affordances in Cabri often with reference to written instructions in the teaching package used. Therefore I suggest that Jakob and Frode's emphasis on orchestration of students' work with Cabri relates well to Instance 1: "Directing students to explore the tasks". Neither 3 nor 4 in the list seem to be related to Jakob and Frode's teaching style and emphasis in teaching. Instance 2, "Emphasises use of technology to discuss the solutions of a task", had some focus as part of teachers' focus on utilisation of the dynamic dragging-function which for example was suggested as a checker for correct made constructions.

Trude always intervened by assisting students one by one with tasks in Cabri in what I denoted as Step 1 in her emphasis. In Step 1 she gave instructions mainly to single students in order for them to be able to investigate techniques in Cabri and succeeding in making for example a construction. She wanted her students to *investigate* Cabri both in, what I denoted as, Step 1 and Step 2. In Step 2 she wanted her students to collaborate and investigate solutions in Cabri. Thus Instance 2 in the list and also at least the final part of Instance 3, "…and stimulating collaboration among students", seem to share characteristics with Trude's orchestration of students' Cabri-use. Since Trude never had any plenary orchestrations with Cabri, besides in an oral form, Instance 4 was not found in her teaching.

Hence, with reference to the list by Goos et al. and the number of instances involved, I argue that Jakob and Frode's support for students' work had a strict form. Trude's support was less strict and included several of the instances in the list by Goos et al.

6.3.2 Goals energising teachers' actions with Cabri

What did Frode and Jakob want to achieve when they, in their step by step orchestrations, had focus on development of successful *techniques* in Cabri, *affordances* including utilisation of these affordances in Cabri supported by teaching operations and, in most of their lesson, a *teaching package*? In their teaching their emphasis was expressed by Jakob and Frode as accurate use of possibilities in Cabri in particular the dynamic dragging-function and other possibilities offered in the menu bar in Cabri. What did Trude want to achieve in trying to *stimulate* students' *collaboration and investigation* of Cabri? I argue that to address these questions give me the possibility to illuminate *teachers' goals* which, according to the activity theory perspective elaborated in Section 3.1, *directed teachers' actions* with Cabri.[29] In activity theory notions, *goals* are personal and conscious to which actions are directed. This privacy of goals also indicates that to illuminate teachers' goals is a difficult task.

[29] Use of the terms goals, actions and operations in this chapter builds on the activity theory perspective, which I elaborated in Section 3.1.

However, by paying attention to what the teachers emphasised when they talked about their teaching and in what I observed they emphasised in their teaching, I believe I am able to contribute with findings about teachers' goals.

In Chapter 5, teachers' implementations of Cabri were analysed utilising activity theory. The analysis illuminated teachers' motives for implementation of Cabri. With reference to Chapter 3 I argued that that motives are oriented to collective objects and *desired outcome* within activity systems and accomplished in teaching energised by teachers' and students' goals and with *achieved* outcome. Thus, I start by referring back to objects and outcome illuminated in Chapter 5.

Trude's goals

In Figure 5.3 (see p. 187), I illustrated the school activity system's proposed activity and actions for teaching geometry at Fjellet and Trude's proposed implementation of Cabri in her teaching activity system. Below in Figure 6.11, her object and desired outcome from the implementation phase is illustrated based on Figure 5.3 where the bold text indicates issues addressed in order to have development in teaching:

OBJECTS	DESIRED OUTCOMES
Implementation and orchestration of Cabri-use in the geometry topic, *building on use of compasses, with students' learning related to requirements in the Curriculum*	***Daring to use and make priority on Cabri and inquiry to fulfil expectations,*** *students and teacher developing skills together*

Figure 6.11: Trude's object and desired outcome with implementation of Cabri

For Trude the very implementation of Cabri was an issue. As part of her participation in the projects, she experienced a desire to fulfil the expectation experienced with Cabri alongside her personal issue of daring to use Cabri. Students' and teacher's developing skills together seemed as elements in her desired outcome which were less problematic to address for Trude.

Findings in Section 6.2 indicate that her *object* and desired outcome were accomplished in teaching and consequently *energised* her *actions*. Thus, they served as goals which stimulated her actions. She made the mentioned arrangements (see Sections 6.2.1 and 6.2.2) and had a two-step focus where students' *collaboration and investigation of Cabri* was the important Step 2 which she wanted to achieve and thus goals for her Cabri-use in teaching. The importance of *daring* to use Cabri in her teaching was an important goal in itself as indicated with the joy Trude expressed (see Section 6.2.3, p. 251).

Jakob and Frode's goals

Similar to Figure 5.3 for Trude, Figure 5.2 (see p. 186) illustrates the school activity system's proposed activity and actions for teaching with Cabri in the teaching activity systems at Grade 8 at Austpark. Below in Figure 6.12, Jakob and Frode's object and desired outcome from the implementation phase is illustrated based on Figure 5.2. The bold text still indicates issues:

OBJECTS

Implementation and orchestration of Cabri-use in the geometry topic, *building on use of compasses, with students' learning related to requirements in the Curriculum*

↔

DESIRED OUTCOMES

Students' use of Cabri to increase motivation and improve scores in tests. Use of ***same tests and teaching package in all classes***

Figure 6.12: Jakob and Frode's object and desired outcome with implementation of Cabri

For Jakob and Frode, implementation of Cabri in the geometry topic was a school issue provoking a tension since they needed to convince at least their mathematics teacher colleague at Grade 8 to implement Cabri in his teaching. Use of the same tests and teaching package were proposed outcomes suggested in their implementation phase based on rules in the school activity system: that every student at a grade should have the same or at least similar teaching and the same tests in mathematics. This explains why it was absolutely necessary that Jakob and Frode's mathematics teacher colleagues Peter at Grade 8 implemented Cabri.

Findings in Section 6.1 indicate that their desired object, implementation and orchestration of Cabri-use in the geometry topic, building on use of compasses, with students' learning related to requirements in the Curriculum were accomplished in their teaching and energised their actions at Grade 8. Their desired outcomes including improved scores in tests, use of the same tests and teaching package in all classes were also achieved. The latter is evident from their arrangements for use of Cabri (see Sections 6.1.1 and 6.1.2). However, their desired outcomes concerning "Use of Cabri to increase motivation" seemed to have had less impact on their orchestration for Cabri-use but energised Jakob's implementation of the free software GeoGebra one year later. Their emphases on students' development of successful techniques and affordances (see Section 6.1.3) also seemed to have worked as goals, were central elements in their Cabri-tests and their desired outcomes with improved scores in tests was achieved. To substantiate that their emphases served as goals for the teachers I refer to examples considered earlier in the chapter. Their focus on utilisation of affordances was evident in Frode's review of the Cabri test where he argued that a construction of a triangle worked if the triangle was connected after utilising the dynamic dragging-function was used (see Appendix 8xviii, p. 351). Jakob and Frode both demonstrated techniques that worked and did not give the suggested result in Cabri and considered consequences of these techniques. This was evident in Jakob's plenary review of the Cabri-test where he demonstrated an unsuccessful techniques used by many of his students in the test (see Appendix 8xvi, p. 349). These efforts indicate that the emphasis on students' successful techniques, affordances and utilisation of affordances with Cabri were energising goals for Jakob and Frode's actions in their teaching. Earlier in this chapter I have argued for minor differences in emphasis in Jakob and Frode's lessons and in what the teachers emphasised when talking about the Cabri-use in teaching. This might indicate differences in teachers' goals such as Frode's more clearly emphasis on improved scores in tests as an important outcome.

Although all three teachers more or less shared the same object of implementation of Cabri, building on teaching with compasses, their desired outcomes were different and so were their goals as indicated in this subsection. Jakob and Frode repeatedly talked about students' *improved scores in tests* and on *long-lasting effects* (see Appendix 8xxix, p. 357) as an important outcome from their use of Cabri. They designed tests which emphasised techniques and affordances in Cabri, and they referred to students' score on these tests as crucial. Trude repeatedly emphasised that her aim was to *dare* start using Cabri and students' *collaboration and investigation* of Cabri together with her as her desired outcome. She too referred to students' outcome and their working effort which she characterised as enormous (see Section 6.2.5, p. 258 with reference to an episode in a workshop, Appendix 8xxxv, p. 359).

6.3.3 Use of Cabri evolving as a cultural tool

Above I have considered Trude, Frode and Jakob's goals which energised their actions when they implemented and started to use Cabri in teaching. In Chapter 3 I referred to the distinction made between *operations* and *actions* in activity theory. *Operations* are *actions* accomplished within the *conditions* of activity where actions occur and involves use of *cultural tools*. This distinction builds on contributions by Leont'ev and elaborations by Kaptelinin (1996) and was outlined in Section 3.1.2 (see p. 61). The operation level has in this chapter been particularly emphasised in Sections 6.1.4 and 6.2.4 where teachers' orchestrations were described referring to their *teaching style* and accomplished *teaching operations*.

The *conditions* for Frode and Jakob's teaching were the booked computer lab at Austpark, installed computer software and students at Grade 8 working respectively mainly in pairs and alone with computers at the computer lab. For Trude, the condition was her classroom where half of her students worked with Cabri on laptops one by one.

The *roles* of teacher and students and ways of working and talking to each other within the conditions, either at computer labs or classroom when using Cabri, are something evolving from day to day. Consequently, when using Cabri the three teachers and students constituted their *own sub-culture*, and within these sub-cultures ways of using and talking about Cabri as a *cultural tool* evolved and were gradually established. Such evolvement of cultural tools through use was illustrated in Figures 3.1 and 3.2 (see p. 59- 60).

Trude accomplished brief oral introductions, presented tasks to be approached with Cabri and led discussions after the Cabri-lessons. Apart from this, her operations were dominated by what I have denoted as her *encouraging teaching style* (see Section 6.2.4) walking around stimulating her students to approach Cabri quite openly and appreciating their efforts. Trude's stimulated *collaboration and exploration* among students particularly by *assisting* some of the students she expressed as being the cleverest and asked them to share their achievements with others. She utilised *pointing* with finger and a number of *positive enthusiastic words* as teaching operations in her orchestration combined with *what if*-questions when students worked with Cabri. Together this indicates her *rules* for the *division of labour* in her class when using Cabri. Trude wanted collaboration between her students together with herself investigating possibilities in Cabri. Altogether these elements contributed in forming use of Cabri as a cultural tool in her class at Fjellet.

Use of the *written teaching package* composed with worksheets contributed in forming Cabri as a cultural tool in Frode and Jakob's classes. The students were supposed to read the written instructions and to solve the tasks in the worksheets supported by teachers' *step by step orchestrations* (see Section 6.1.4) of both single students and in plenary. These orchestrations were guided by visual presentation and had as mentioned an emphasis on students' development of *techniques* and *affordances* in Cabri. Like Trude, Jakob and Frode utilised a number of *teaching operations* in their orchestrations (see Section 6.1.4). Overall during Frode and Jakob's plenaries, the students were mainly supposed to listen, look and contribute respectively to Frode and Jakob's operations in Cabri. Afterwards or simultaneously, students were supposed to accomplish similar operations on their computer, orchestrated by the instructions in the teaching package or tasks given or presented by Jakob or Frode. This also indicates the rules and division of labour evolving in Jakob and Frode's classes considered in the analysis in Chapter 5. Hence, the teaching package supported by Jakob and Frode's orchestrations of students' work contributed in forming Cabri as a cultural tool at Austpark.

The paragraphs above have summarised how Cabri can be considered to have been established as a cultural tool in Trude, Frode and Jakob's class. The role of students, teachers' oral and visual orchestrations and the role of the teaching package have been emphasised. Although my study has a focus on teachers' roles, concerns for students' opportunities for learning within the evolution of these different cultural tool will be considered in Chapter 7.

6.3.4 Teachers' instrumental orchestrations of Cabri

In this section I utilise the instrumental approach elaborated as a theoretical perspective in Section 3.2 particularly building on contributions by Trouche. I pay attention to how the three teachers orchestrated the *instrumentation* and *instrumentalisation* processes when Cabri was used in teaching. Earlier in the thesis I made the following simplified distinction between instrumentation and instrumentalisation as processes involved in my study of Cabri-use (see Section 3.2.1, p. 74):

> I interpret *instrumentation* to be about getting to know what Cabri affords, how Cabri represents mathematical concepts and properties and development of abilities to use the tool. *Instrumentalisation* is about utilising and investigating in different ways the affordances offered by Cabri.

The orchestrations of these two processes are considered related to teachers' *teaching style* and the role of their *teaching operations* (see Sections 6.1.4 / 6.2.4) and their emphasis in teaching (see Sections 6.1.3 / 6.2.3) building on their arrangements for Cabri-use (see Sections 6.1.1 and 6.1.2 / 6.2.1 and 6.2.2). Thus, the instrumental approach contributes to what in activity theory is denoted as operations within conditions considered in the previous section and denoted as the *third* level of activity (see Section 3.1.2, p. 62). The analysis also utilises Trouche's distinction between the *main* and *secondary objectives* of teachers' orchestrations. Below, I first pay attention to Frode and Jakob's instrumental orchestrations of Cabri-use and later, from page 268, on Trude.

Jakob and Frode mainly orchestrating the instrumentation process

Orchestrations of the instrumentation process were in Jakob and Frode's classes closely related to the teaching package. The package introduced students to what Cabri afforded and how to use Cabri which I consider as crucial elements in the instrumentation process with Cabri. To use Cabri *accurately* was repeatedly emphasised by Jakob and Frode in Cabri-lessons both when the teaching package was used and not. As evident from Section 6.1.3, *accurately* use of Cabri relates to students' use of *techniques* giving a successful result when working with the mathematical representations afforded its users by Cabri. Consequently, both the teaching package and teachers' emphases indicate that the *instrumentation* process was extensively orchestrated in Jakob and Frode's Cabri-lessons.

What consequences for students' experience with Cabri and learning of the geometrical concepts and properties underpinning use of Cabri can be made based on this emphasis in the instrumentation process? To which extent did the students' experience *why* the constructions in Cabri worked? Earlier in this chapter (see Section 6.1.1) I commented on the content of worksheets in the teaching package which Jakob and Frode used in most of their Cabri-lessons (for examples of worksheets see Appendix 2). Findings in Section 6.1, indicate that Jakob and Frode in their orchestrations only to a small extent emphasised *why* the constructions worked, instead emphasising *how* to accomplish the tasks in the worksheets. As an example, when considering construction of 60 degree angles Jakob, in his plenary, focused on how to move the mouse pointer *accurately* in order to have a successful construction. The only time I observed that Jakob emphasised why the 60 degree construction would work was in the review of the Cabri test when he mentioned that the circles became equal. Similarly also Frode paid little attention to the why aspect in his orchestrations, except emphasising *precise oral* description of criteria in constructions. An example is when Frode in his orchestration emphasised, as a criterion, the importance of keeping the same compass lengths. This occurred both in a classroom lesson with compasses and in the following Cabri-lesson at the computer lab on the 18th of January. Findings also indicate that both Jakob and Frode stimulated the *instrumentation* process when assisting their students to discover the "world" of Cabri, emphasising affordances like measuring lengths and angles and in particular the dynamic dragging-function. Altogether, teachers' emphasis on the instrumentation process made students' aware of and quite capable to use techniques and affordances in Cabri in accordance with their focuses in teaching, but with minor concerns for students' development of utilisation and investigation of geometrical properties and tasks with Cabri.

Related to their emphasis on the instrumentation process Jakob and Frode through their orchestrations also stimulated the *instrumentalisation process* but I argue in a very limited way. As findings in Section 6.1.4 reveal, students' work with Cabri was quite strictly orchestrated linked to either work with the tasks in the teaching package or to repeat the solution process of tasks presented by Jakob and Frode. Consequently, I argue that both Frode and Jakob's orchestrations of the *instrumentalisation process* was *limited*. The main observed support of the instrumentalisation process in teachers' orchestrations, was to assist in students' development of *utilising* the *dynamic dragging-function* to *verify* if constructions had been made *accurately*. This is evident when considering Jakob's review of the Cabri test on the 7th of February, where he suggested his students to utilise the dynamic dragging-function in Cabri to *verify constructions*.

Overall, Jakob and Frode's students acquired little experience in using Cabri apart from doing the tasks in the teaching package and repeating tasks presented in quite detailed ways by Frode or Jakob. Hence, there was little focus on students' use of Cabri in a more free investigative way. Interestingly, Jakob himself demonstrated what I have denoted as *Jakob's special technique for measuring angles* (see Section 6.1.3, p. 215). This example illustrates that he himself had gone through an instrumentalisation process with Cabri while he did not emphasise students' instrumentalisation process with Cabri.

Throughout in meetings and conversations, both Jakob and Frode brought up considerations concerning the role of problem solving, explorative tasks and inquiry, which was discussed in Section 6.1.5. They both expressed that the teaching package arranged well for individual work with structured tasks and had been sensible for the students and for their own orchestration of the lessons. Only one exception to this view has been observed; in a short reflection conversation with Frode. In utterance 11 from this conversation he expressed that his and Jakob's approach not had been an appropriate choice (see p. 237). He continued, in utterance 13, suggesting: "I think we rather should have given them problem solving tasks". However, the main view expressed many times by both of them was that they rather would work more investigatively with Cabri when their students entered Grade 9. To *work more investigatively* could mean that their students would be freer to *utilise affordances* in Cabri in personal ways stimulating the instrumentalisation process.

Thus, based on what I have argued in this subsection I conclude that *Jakob and Frode mainly orchestrated the instrumentation process*. Over and over again they both emphasised affordances in Cabri and use of techniques which they considered as successful in Cabri.

Trude mainly orchestrating the instrumentalisation process

Above I have argued that Frode and Jakob orchestrated the instrumentation process by emphasising students' use of successful *techniques* in Cabri and *affordances* offered in Cabri, but with less focus on instrumentalisation process. Trude, on the other hand, had a main emphasis on students' *collaboration* and *investigation* of Cabri denoted as Step 2 in her emphasis (see Sections 6.2.3 and 6.2.4). She expressed pleasure when observing students' successful investigation of affordances, which she expressed during the LCM Workshop 10 early in January. In the same workshop Trude emphasised how her orchestration in a Cabri lesson resulted in what she interpreted as *excellent learning* (see comments on pages 251 and 256 with reference to Appendix 8xxxiii, p. 358). She described the excellent learning occurring when her students, almost without her assistance *investigated* the tool, *shared* ideas and *checked* their solutions by *utilising* the *measuring affordance* in Cabri. Her way of valuing this effort indicates that it was a way of teaching she really wanted to experience.

Her appreciation could also be stimulated by her interpretation concerning how she believed she was expected to teach since similar approach to use of computer software tools had been proposed by Otto, one of the didacticians in the ICTML project. Findings from analysis in Chapter 5 indicate that Trude experienced such expectations from didacticians as part of her participation in the ICTML project. Trude also expressed a great wish of having inquiry implemented in her teaching, although she questioned whether her efforts could be seen as provoking inquiry in her teaching. However, in Section 7.3.2 I conclude that analytical findings in Section 6.2 indicate that Trude's approach and efforts with her students can be characterised through the expression *inquiry as a way of being*. Altogether, her orchestrations typically stimulated students to investigate Cabri, which I regard as being orchestration *mainly* of the *instrumentalisation* process.

The *instrumentation* process was to some extent orchestrated by students themselves when assisting each other. Trude too orchestrated this process when she briefly assisted some of the students in their investigation of techniques and utilisation of affordances in Cabri (see Step 1 in her emphasis in Sections 6.2.3 and 6.2.4). However, as I indicate in Section 6.2.3 this emphasis seemed only to be an intermediate emphasis where the Step 2 considered above had the most emphasis both in time and in Trude's efforts.

Teaching operations and objectives of teachers' orchestrations

Jakob and Frode utilised a number of *teaching operations* in their orchestrations such as *numbering* menu options in Cabri and introducing terms such as *glue* and *fastening* in their orchestrations. When working with the menu bar in Cabri, Frode pronounced *loudly* the name of the menu options while he selected them. Trude's main teaching operation was her use of *positive enthusiastic words* as well as her *pointing* and *tracing* with finger at students' screen especially in the intermediate phase, what I have denoted as Step 1 in her emphasis. Frode and Jakob used *pointing* and *tracing* at students' screens too, although Frode was critical about pointing and especially about taking over the computer mouse. He wanted to rather place his arms at the back. He never said explicitly why he suggested placing his arms at the back but I assume it was in order for students to be in control of their work and he himself not falling into the trap of taking possession of the computer mouse.

In Section 3.2.3 (see p. 79), I referred to the distinction between the *main* and *secondary objectives* of an orchestration suggested by Trouche (2004). Simplified, the secondary objective relates to what a teacher wants to achieve with the orchestration, while the primary objective is the need for the orchestration. The *main* objective of Jakob and Frode's orchestrations typically occurred because their students' used Cabri inaccurately as it was phrased by Jakob and Frode, a technique that Jakob and Frode considered as not working well in Cabri. The *secondary* objective of their orchestrations were accomplished through teaching operations like those listed above mainly stimulating the instrumentation process involving development of successful *techniques* in Cabri and experience *affordances* in Cabri. Trude's teaching operations focused on stimulating students' utilisation of Cabri investigatively and collaboratively by sharing their achievements. This I consider as her secondary objective of her orchestrations. Trude's main objective was to stimulate for the secondary objective by assisting briefly some of her students to investigate techniques and utilise affordances in Cabri making sure they had something to share and investigate.

Characterising Jakob, Frode and Trude's instrumental orchestrations

In this final subsection I discuss differences in teachers' instrumental orchestrations highlighted earlier in this section (6.3.4) by utilising Trouche's three *stages of instrumentalisation* process introduced in Chapter 3. In this section (6.3.4), I have argued that Jakob and Frode mainly orchestrated the instrumentation process while Trude mainly orchestrated the instrumentalisation process but also the instrumentation process in an intermediate phase. To supply the argument for Trude's greater emphasis on the instrumentalisation process than Jakob and Frode, I discuss the three teachers' orchestration of the instrumentalisation process by referring to an earlier quoted contribution by Trouche (2005a) (see Section 3.2.3, p. 78). Trouche identifies *instrumentalisation* as a process with *three stages*. The same quote is repeated below:

> The instrumentalization process, directed by the subject, involves several stages: a stage of *discovery* and *selection* of the relevant keys, a stage of *personalization* (one fits the tool to one's hand) and a stage of *transformation* of the tool, sometimes in directions unplanned by the designer… (Trouche, 2005a, p. 148)

I argue that Frode and Jakob with their emphases in teaching in a restricted way orchestrated stage one but not or very limited stage two and three. By their emphasis on techniques and affordances in Cabri related to the instrumentation process, Jakob and Frode also prepared for students' instrumentalisation of Cabri in that students' were supported to utilise affordances, especially the dynamic dragging-function to verify a construction. Trude's orchestrations supported a more *investigative* approach in stage one, "discovery and selection of the relevant keys", and also laid the foundation for stage two, students' customising of the tool. Consequently, Trude apparently stimulated the instrumentalisation process more broadly.

I end this chapter discussing Jakob, Frode and Trude's orchestrations of Cabri-use in relation to *three levels of instrumental orchestrations* proposed in Trouche (2003; 2004). His description of the *first* level of instrumental orchestrations from a teacher indicates a focus on assisting students to use the tool and utilise possibilities in the tool. This corresponds well with Jakob and Frode's emphasis on successful techniques, affordances and utilisation of affordances in Cabri. Trude also had emphasis on this level of orchestration but spent less time on assisting students in use of the tool.

The *second* level orchestrations are by Trouche described as having more focus on psychological aspects of instruments where teachers are monitoring students' instrumental genesis. In my study, the teachers assisted students in their work by utilising tasks, teaching packages and by interventions either for single students, a group of students or in plenary. Analytical findings earlier in this section (6.3.4), indicate that a difference was observed concerning to which of the processes, instrumentation and instrumentalisation, the three teachers directed their orchestrations. Trude was mainly orchestrating the instrumentalisation process and only in an intermediate phase orchestrated the instrumentation process. Jakob and Frode more narrowly orchestrated the instrumentation process. Their use of a teaching package highlighted their constraining of students' operations to this emphasis. I argue that *all* the three teachers' orchestrations supported development of instruments. However, because of Jakob and Frode's more narrow focus on orchestration of the instrumentation process, I characterise their orchestrations as being only *partly* the second level. Trude's orchestrations seemed broader where both processes seemed to have been supported. Thus, Trude's instrumental orchestrations supported this second level more than Jakob and Frode.

The *third* level of orchestrations is by Trouche described as dealing with relationship of students' operations with one or more instruments on a more reflective level. According to Trouche, this corresponds to learning environments where students' self analysis dominates and where mediation with the processes of instrumentalisation and instrumentation work smoothly. The analysis indicates that Trude's way of orchestrating her teaching and the goals stimulating these orchestrations seemed close to the described third level by Trouche. Trude wanted and expressed that she had observed "excellent learning". However, the students were yet novices in using Cabri and probably needed more experience in order for the two processes to "work smoothly" as argued by Trouche. Analytical findings from Jakob and Frode's orchestration of Cabri-use indicate that their orchestrations not were supporting students' self analysis. Jakob and Frode's commented that they believed their students would be able to utilise Cabri more investigatively at Grade 9 with the basis from Grade 8 indicates teachers' awareness of a narrow focus in their orchestrations.

Finally, the fact that Jakob, Frode and Trude all based their teaching with Cabri on students' experience from earlier or simultaneous work with compasses, also meant that their teaching to some extent supported *both* the instrumentation and instrumentalisation process. Their students had already potentially experienced many of the terms offered in Cabri and comparable ways of accomplishing constructions with compasses. Thus, students' instrumental genesis of Cabri were potentially simplified by their experiences from compasses and made the orchestration-requirements on the teachers less than if students not had experienced use of compasses. This is particularly evident with Jakob and Frode who utilised references to experience from constructions made, with respectively *compasses and Cabri,* as a teaching operation, and talked about constructing in a *Cabri-way* when using compasses. In their orchestration of Cabri-use they utilised *transparency* of Cabri to paper and pencil work with compasses which Haspekian (2005) considers as an advantage with Cabri. The vocabulary involved and the visual looks with Cabri and compasses are more transparent than spreadsheet and paper and pencil potentially making the instrumentation process easier with Cabri than with a spreadsheet package.

Conclusions based on differences in teachers' orchestrations of Cabri-use, will be presented in Chapter 7 with implications for students experiences and learning.

7 Conclusions and implications

In Chapters 5 and 6, I analysed three teachers' implementation and orchestration of Cabri-use in mathematics teaching. The study of the teachers was situated within developmental projects emphasising computer software use and an inquiry approach in mathematics teaching as indicated in Section 1.2 and discussed throughout the thesis.

In this final chapter I revisit my research questions, present conclusions and propose implications. This is done through a synthesis of concepts and examination of the theoretical framework supporting the analysis in Chapters 5 and 6. Within the chapter, critical examination of implications which can be drawn is emphasised. The thesis emphasises teachers' implementation and first ever use of a particular computer software tool, the DGS[30]-package Cabri, in teaching. Despite this I formulate most of the implications as implications for implementation and orchestration of the use of any new computer software tools in teaching and only a few places argue that the implications applies just for Cabri or DGS. Key points in this chapter are discussion of the role of developmental projects and National Curricula for development in mathematics teaching, implications concerning the nature of schools and the role of collaboration between teachers for sustainable development at schools. In the final section (7.5) implications are summarised and formulated for researchers and policy makers (7.5.1) and teachers (7.5.2). In Section 7.5.1 I also give suggestions for further research and developmental projects.

7.1 Revisiting the research questions

The research questions were formulated in Chapter 1 (see p. 23):

1) With what *motives* and *goals* do teachers at Grade 8 *implement* and *orchestrate* Cabri-*use* in mathematics teaching?
2) What characterises teachers' initial *orchestrations* of Cabri-*use* in mathematics teaching at Grade 8?

In my treatment of conclusions and implications related to these research questions, I divide Research Question 1 into two parts which I denote a) and b):

1 a) With what *motives* do teachers at Grade 8 *implement* Cabri in mathematics teaching?
1 b) With what *goals* do teachers at Grade 8 *orchestrate* Cabri-*use* in mathematics teaching?

Section 7.2 contains conclusions and implications related to Research Question 1a, Section 7.3 to Research Question 2 and Section 7.4 to Re-

[30] DGS as an abbreviation for a dynamic geometry software package such as Cabri was introduced on page 32.

search Question 1b. This division of content has been made because of the different concepts and theoretical perspectives involved. Teachers' motives (7.2) visible in their implementation process were in focus in Chapter 5 and teachers' orchestrations of Cabri-use (7.3) in Chapter 6. Teachers' goals (7.4) were emphasised in both Chapters 5 and 6. Thus, I argue conclusions and implications concerning teachers' goals gain from being presented after the two other subsections.

Throughout the thesis I have quoted contributions by Leont'ev (see p. 61) and successors accounting for three different levels; activity ↔ motive; actions ↔ goals; operations ↔ conditions. In Chapter 3, I argued that activity theory and the instrumental approach support researchers offering *supplementary* lenses to analyse teachers' development in teaching related to these three levels. As quoted in Chapter 2, researchers such as Monaghan (2004) and Fitzsimons (2005) have used frameworks which included both activity theory and the instrumental approach (or a related theory within the French research) in analysis of teachers' practice with ICT in mathematics teaching. Thus, my thesis gives contribution to analysis of teachers' implementation and use of ICT in mathematics teaching guided by these two perspectives.

The style of Sections 7.2 – 7.4 is that I first draw out key findings related to the three teachers and then offer a more general synthesis towards the end of each section. In the final section (7.5), key implications are presented for the different groups of readers; teachers, policy makers and researchers.

7.2 With what motives do teachers at Grade 8 implement Cabri in mathematics teaching?

Analytical findings in Chapter 5 revealed reasons, issues and external influence on teachers' *implementation* of Cabri. I argued that these analytical findings illuminated teachers' *motives* for implementation of Cabri. This was done by utilising three kinds of *activity systems* to analyse development of *collective objects* in mathematics teaching during teachers' implementation process of Cabri.

The connection between motives and objects in activity is evident from the elaboration in Chapter 3 where it was argued that a *motive* can become a *collective object* in an activity system. With reference to Cole (1996) it was emphasised that the community in an activity system refers "to those who share the same general object". It was also argued that teachers' efforts to expand motives into collective objects in an activity system indicate what the teachers want to achieve, their *goals*.

I have accounted for the two developmental projects as one activity system which I denoted the KUL activity system. I argued that the KUL activity system proposed actions for *intersecting activity systems* at each school; a collective school activity system and teaching activity systems. These three kinds of activity systems were described in Section 3.1. When I analysed teachers' motives for implementation of Cabri, intersections of these activity systems were illustrated (see Figures 5.1 - 5.3 in Chapter 5) where the role of *tensions* and *issues* were highlighted. Findings in Chapter 5 pinpointed that the external influence from the National Curriculum and teachers' participation in the developmental projects influenced teachers' implementation process.

Section 7.2.1 contains conclusions and implications related to findings of external influence on teachers' motives. Section 7.2.2 gives more broadly conclusions and implications of teachers' motives where issues addressed in the implementation process are highlighted.

7.2.1 External influence on teachers' motives

What kinds of influence do curriculum guidance and didacticians' support in sessions, such as workshops, meetings and visits in teaching, have on teachers' implementation of Cabri or other kinds of computer software tools not previously used by the teachers in their teaching? With reference to statements in the National Curriculum in Norway, I have introduced the term *double innovation* (see p. 35) to indicate the kind of expectations recognised for teachers' use of computer software in teaching:

> To utilise computer software whenever appropriate *and* in an investigative way (building on statements in the Norwegian National Curriculum from 1997)

The teachers in the ICTML project seemed well aware of such statements in the mathematics part of the Curriculum. Spreadsheets are the only computer software tool explicitly mentioned but others are supposed to be used investigatively whenever suitable. However, for many teachers in Norway spreadsheets have been the only computer software tool used in mathematics lessons such as for the three teachers in my study ahead of the projects. This illustrates a *tension* for teachers with regard to statements in the Curriculum. Statements in the Curriculum indicate that other computer software tools should be used and in an investigative way which might be neither tools nor a kind of approach teachers typically adopt in their teaching. In addition, a similar *double innovation* expectation and tension was recognised for the teachers participating in the ICTML project considered in this thesis:

> To utilise computer software tools *and* implement inquiry in teaching (building on statements in the ICTML project)

Teachers in my study did experience didacticians' contributions as *support* for implementing Cabri and development in their use of spreadsheets, the latter being a tool all of the teachers had some experience with in teaching. Particularly Trude experienced the support as *expectation* for implementation of computer software tools combined with inquiry in teaching. Consequently, I argue that teachers' commitment to the projects and experienced expectation strengthened the tension for teachers not used to utilise computer software investigatively and who had never used Cabri in teaching.

When considering development for an activity system, I introduced the activity theory term *expansion* (see Section 3.1.5) to describe the possibilities and changes provided by teachers' efforts to address issues and cope with tensions in their implementation of Cabri. I claim that teachers' participation in the developmental project influenced their *expansion* of Cabri as part of an *object* within their teaching activity systems and school activity systems and contributed to their motives for implementation of Cabri. However, other teachers in the project did not implement Cabri. Altogether, based on these findings I argue:

- Mathematics teachers experience the tension of implementing "new" computer software tools as hard to overcome since it involves a new tool and potentially generates a need for changes in teaching. Teachers also question benefits of utilising tools like Cabri in favour of more time to other tools such as compasses.
- Driven by aims in developmental projects and commitment to research and development, didacticians can support teachers to implement such new tools and teachers can support each other. This was evident in my study with didactician Otto's explicit support at Fjellet, where he undertook some lessons with spreadsheets, and the teacher Jakob's entrance at Austpark. The role of Jakob and Otto is similar to what Crisan et al. (2007) argue as "the importance of key persons promoting ICT within the department".
- To fulfil *double innovations* is very demanding for teachers. Thus, the kinds of innovation requirements in the National Curriculum in Norway and the ICTML project might be insufficient and experienced as a burden for teachers who consider implementation of new computer software tool in teaching. This is in accordance with a similar double innovation concern raised in Barzel (2007). It also supports the claim by Monaghan (2001) that researchers and policy makers often propose ICT almost as a tool to develop the style of mathematics teaching (see Section 2.2.4, p. 37). Although all the three teachers in my study managed to implement Cabri, only one of them, Trude, seemed to have managed to respond to the double innovation request through her initial orchestration of Cabri-use in teaching.
- Lack of inclusion of any other computer software than spreadsheets in the National Examination in mathematics at Grade 10 in

Norway, has made institutional support in the implementation process of a new computer software tool difficult for teachers. By institutional support I include students, parents, other teachers and leaders at schools.

7.2.2 Issues and reasons for teachers' Cabri-implementation

Above I concluded that external influence from requirements in Curriculum and the ICTML project contributed to why the three teachers in my study implemented Cabri. In this section I conclude how other reasons and issues influenced teachers' implementation.

Findings in my study indicate that the two teachers from Austpark, Jakob and Frode, expressed at least four other main *reasons* and five *issues* in their implementation process of Cabri (listed in Chapter 5, p. 154). These were school institutional issues which when addressed worked as reasons for their implementation such as involvement of colleagues, design of common tests with Cabri and access to equipment.

Jakob, Frode and also the third teacher in my study, Trude at Fjellet, saw a possibility to take advantage of using both Cabri and compasses in geometry teaching. Jakob and Frode hoped that the emphasis on Cabri would help to improve students' achievements with compasses. To reserve extra time for Cabri was argued to be a necessary condition for the implementation by all the three teachers since a new tool would be demanding both for teachers and students.

Trude had a main focus on two reasons and one main personal issue in her implementation process of Cabri in mathematics teaching. Her main issue was to dare to start using Cabri and to let students work collaboratively and investigatively despite her own expressed lack of competences in using computer software. This finding is similar to a main implication proposed by Engström (2006). Engström claims that teachers need to dare to use Cabri investigatively. Trude's experienced external expectations to implement computer software such as Cabri and her decision to reserve extra time to Cabri were reasons for her implementation of Cabri.

Based on these analytical findings I conclude that Jakob and Frode's implementation of Cabri seemed more complex than Trude's implementation of Cabri. With reference to activity theory notions, Jakob and Frode had to cope with many school institutional issues in order to have an *expansion* of a *shared object* which included implementation of Cabri in their school activity system at Grade 8. In the activity theory analysis in Chapter 5, issues were revealed and seen as indicating that teachers coped with *tensions*. Issues or factors influencing teachers' practice with ICT and implementation of new computer software tools in teaching have been emphasised by many researchers. In relation to this, I quoted contributions by Goos (2005), Berry, Graham, Honey, and Headlam (2007), Crisan et al. (2007) and Mumtaz (2000) in the literature review in Section 2.2. In Crisan et al., a distinction is made between contextual and personal factors influencing teachers' implementation process of ICT in mathematics teaching. My analytical findings indicate a similar difference in the *nature of issues* considered by teachers at different schools in their implementation process, and I argue:

- Differences in the nature of issues teachers cope with could be related to the extent of *collaboration among mathematics teachers* which was evident with reference to Fjellet and Austpark.
- At schools where teaching in mathematics is governed by institutional rules, implementation processes of new tools are more complex since teachers have to collaborate and agree in order to have development in teaching. An institutional rule evident at Austpark was the use of the same mathematics tests reflecting the content of teaching.
- Implementation of new tools at schools with collaboration among teachers has potential to give more sustainable development because the implementation process is collaboratively and less individually dependent than at schools with minor collaboration.
- Factors such as access to equipment and reserve of extra time to manage to accomplish implementation of a new tool are conditions for potential implementation of new computer software tools such as Cabri.
- Teachers' awareness of available teaching packages and possibility to utilise Cabri in relation to teaching with compasses might support implementation processes of individual teachers and groups of teachers. This was evident in my own study where Jakob and Frode succeeded in including Eivind in the implementation of Cabri at Grade 8 at Austpark. Eivind was the third mathematics teacher at Grade 8 beside themselves but he was not participant in the developmental projects.

The implications in this section add to previous research findings of teachers' implementation of new tools. The implications suggest that the kinds of issues and tensions involved in the implementation process, the external influence and the role of collaboration among teachers at schools influence teachers' motives for implementation of new tools in mathematics teaching and the sustainability of this development in teaching.

7.3 What characterises teachers' initial orchestrations of Cabri-use in mathematics teaching at Grade 8?

In the analysis in Chapter 6, *the instrumental approach* was utilised as a theoretical perspective when characterising teachers' orchestration of Cabri-use. It was argued that this analysis illuminated the *third* level of activity proposed by Leont'ev, operations ↔ conditions.

In Section 7.3.1, I summarise analytical findings related to teachers' *arrangements*, *emphases* and *styles of teaching*, and, based on this, I present conclusions and implications for orchestration of computer software use in teaching. In Section 7.3.2, conclusions from Section 7.3.1 are considered further by emphasising the role of inquiry in Cabri-teaching and opportunities for students' achievements. Finally, in Section 7.3.3 I offer conclusions and implications for researchers utilising the instrumental approach in analysis of teachers' orchestration of students' use of computer software tools in mathematics teaching. The latter is in the theory covered in the analytical term *instrumental orchestration*.

7.3.1 Arrangements, emphases and styles of teaching

Teachers' arrangements for use of computer software tools

In Chapter 6, I characterised Jakob and Frode's arrangement for Cabri-use with two pillars:

1. Use of a teaching package with written instructions for students' work with Cabri.
2. Co-ordinated use of Cabri and compasses in teaching close in time where the design of Cabri-tests was crucial in order for the teachers to check students' outcome.

Jakob and Frode argued for their arrangements claiming that use of Cabri could strengthen students' achievements with compasses. They also expressed the view that students needed to learn to use Cabri first, while working more investigatively or inspired by inquiry could come at a later phase. Jakob and Frode emphasised that their chosen arrangement supported working conditions in teaching that were possible to manage for them as teachers. In general, teachers' relief of having pre-made teaching packages available is evident from the list of issues in Goos (2005) quoted in the literature review (see p. 38). The availability of such packages is according to Berry et al. (2007) important when teachers consider use of new tools and explains claims in Laborde (1993; 2001) that teachers often find it demanding to develop teaching material themselves. Thus, Jakob and Frode's decision to use the pre-made teaching package and expressed relief of having it available is in line with previous research findings. Its availability might in fact be a reason why they decided to implement Cabri.

Trude's arrangement was characterised with two similar pillars but each of them having a slightly different role:

1. Use of Cabri guided by tasks presented on a flip-chart with no further written instructions.
2. Use of Cabri some weeks after students had been using compasses in geometry.

Trude wanted to utilise students' experience from working with compasses in geometry. With this background, she argued that at least some of the students would be able to investigate and succeed with the tasks in Cabri and share their achievements with the other students and her. Like Jakob and Frode, Trude argued for her arrangement by highlighting manageable working condition for her as the teacher. She decided that only half of her class worked with Cabri simultaneously while the other half worked with tasks in their textbooks without any expected big need for assistance.

To summarise, the three teachers' Cabri-use in teaching took advantage of students' experience from use of compasses. This together with other arrangements, such as teaching half of the class at a time (Trude) and use of a teaching package and plenaries (Jakob and Frode) contributed to a decrease in time needed to assist students individually. From the findings and conclusions of teachers' arrangements in my study, I suggest the following conclusions and implications:

- Teachers make arrangements in teaching which guide both students' work with computer software tools and teachers' support of students' work.
- Students who have experience from work with compasses on similar geometrical content as emphasised in Cabri-lessons, are able to use Cabri with less need for instructions. These students also have better possibilities to support each other more efficiently than students without previous experiences from compasses.
- Co-ordinated use of compasses and Cabri close in time can be time-efficient since students can benefit from their experience with compasses in later lessons with Cabri and vice versa.

Related to these implications, students' achievements with Cabri and what students benefit from working with Cabri are discussed in Sections 7.3.2, 7.3.3 and 7.5.2.

Emphases and styles of teaching in Cabri-lessons

Analytical findings in Chapter 6 pinpointed several *emphases* in teachers' teaching. In Jakob and Frode's Cabri-lessons, the two main emphases were on:

1. Students' development of successful techniques. In teachers' Cabri-lessons this was visible by their repeated focus on students inaccurate use of Cabri and thus on how to use the tool accurately.
2. Affordances and students' utilisation of affordances in Cabri

where in particular utilisation of the dynamic dragging-function to verify successful use of Cabri was emphasised.

Two main emphases were also observed in Trude's Cabri-lessons where the latter was given most emphasis in respect to time and effort:

1. Students' investigation of techniques and utilisation of affordances in Cabri such as ability to construct perpendiculars and utilise the dynamic dragging-function.
2. Students' collaboration and investigation with Cabri such as discovering and verifying ways to find the circumscribed circle to a triangle.

Consequently, a major difference was evident between Trude on the one side and Jakob and Frode on the other. The emphases in Trude's lessons were related to students taking control and being in charge of their own and the other students' work, while Jakob and Frode's emphases were directed to each students' personal work with learning to use Cabri. All of them had a focus on utilisation of affordances but with a difference. Jakob and Frode mainly orchestrated students' use of the dynamic dragging-function as a checker for constructions made, while Trude asked her students to find different ways to approach tasks and discuss these different approaches with the help of the dynamic dragging-function. This difference in utilisation of the dynamic dragging-function is in accordance with the two fold distinction between *test mode* and *search mode* considered by Hölzl (2001) and commented in the literature review (see p. 45). The kind of emphasis of Jakob and Frode seemed to be on the *test mode*, while the investigative utilisation Trude emphasised was on the *search mode*.

In Chapter 6, analytical findings concerning how the teachers' accomplished the emphases in teaching illuminated *teachers' styles of teaching* in Cabri-lessons and *teaching operations* (see p. 49) exploited by the teachers. Thus, before I propose conclusion and implications from teachers' emphases, I present key findings of teachers' teaching styles and teaching operations. Later, in Section 7.4, I relate teachers' emphases in lessons to their goals for students' work and learning of geometry.

1. Jakob and Frode's style of teaching was characterised as *supportive* with *step by step* orchestration where they as teachers posed questions and assisted students in their work with Cabri. The teachers intervened when they observed students' lack of success with techniques and affordances in Cabri. A minor difference in their teaching styles was observed. Both in lessons with compasses and Cabri, Frode accomplished longer teacher-led plenaries than Jakob.
2. Trude had an *encouraging teaching style* in her Cabri lessons. She assisted students' in their investigation of techniques and then

challenged the students to share their achievements with each other, help each other and investigate Cabri such as utilisation of affordances in Cabri.

The main *teaching operations* exploited by the teachers were:

1. Jakob, Frode and Trude repeatedly utilised *pointing* and *tracing* with their fingers at students' computer screen when assisting students. Trude combined these teaching operations with *direction words* such as "there", "a little to the left" and so on.
2. Jakob and Frode also sometimes took *possession* of students' computer mouse although Frode expressed this as an undesirable intervention into students' work.
3. All the three teachers utilised more general teaching operations like *rephrasing* questions and *enthusiastic* speaking. The latter was often expressed by Jakob and Frode through loud voice speaking while Trude repeatedly combined her enthusiasm with lots of positive valuing words.
4. Jakob and Frode introduced the terms *hook* and *glue*, and they *numbered icons* in the Cabri menu bar to support their emphasis in teaching on accurate use of Cabri guiding students' development of successful techniques in Cabri.

Jakob and Frode's *styles of teaching* seemed almost unaltered in Cabri-lessons and lessons with compasses. I have a limited basis for concluding whether Trude's observed teaching style was special for her Cabri-lessons although findings from analysis in Section 6.2.4 (see p. 256) suggest that her teaching style in Cabri-lessons was not entirely typical for Trude.

Based on these key findings of teachers' teaching operations, styles of teaching and emphases in Cabri-lessons, I argue more generally:

- An investigative and collaborative emphasis in Cabri-teaching is possible in an initial phase in Cabri-teaching. It is supported when students are requested and challenged to share achievements with each other and have some previous experiences with the geometrical content from use of compasses.
- If only approximately 10 times 45 minutes is available for initial use of a computer software tool such as Cabri, use of a teaching package and plenaries might be an efficient way to support students' development of constructing successfully and utilising affordances in Cabri.
- Teachers' teaching operations highlight teachers' emphases. Their teaching operations are both tool specific such as reference to menu bars in the software and more general such as rephrasing questions.
- In the literature review I quoted Monaghan (2001) Kendal and

Stacey (2001) and Cuban et al. (2001) arguing for an often observed consistency in a teacher's mathematics teaching with and without ICT. Findings in my own study support this claim where I observed Jakob and Frode's similar styles of teaching in Cabri-lessons and lessons with compasses. However, use of "new" computer software tools in teaching can offer teachers a medium to develop an *inquiry mode of teaching.* This is considered further in the coming section with reference to Trude, and indicates that computer software tools can support development in teaching styles as claimed by Kerr (1996).

I argue that teachers' emphases in teaching indicate what the teachers wanted to achieve, their goals, with the Cabri-use. Thus, teachers' emphases will be considered further in Section 7.4 where I offer conclusions and implications of teachers' goals.

7.3.2 The role of inquiry in teaching with Cabri

Analytical findings presented in Chapters 5 and 6 indicate that Jakob and Frode did not consider their Cabri-use to have involved any or at least very little inquiry. They expressed the view that *inquiry* rather would be beneficial when the students were more experienced with Cabri. This is a similar progression found by Monaghan (2004) in his study quoted in Chapter 2. Monaghan denotes this as a "quite natural development"; that teachers first emphasise students' learning to use the tool and then utilisation of the tool for learning mathematics. Jakob and Frode believed that students' achievements would be best if they waited with inquiry seen in the perspective that they as teachers had a limited time to reserve for use of Cabri.

Compared to Jakob and Frode, Trude did *not* seem to make the same kind of distinction between learning to use the tool with successful techniques and working with more inquiry tasks later. Instead she wanted an environment where the students and she investigated Cabri. Trude commented several times how she experienced an expectation and really wanted to be able to have inquiry and use of computer software in her teaching. When she commented on her teaching she expressed great joy with her use of Cabri. The latter indicates her *personal triumph* in daring to use Cabri and letting her students investigate and collaborate in utilising the tool despite her expressed lack of self-confidence in use of computer software. I consider the difference in emphasis on inquiry to be related to teachers' different implementation processes and I conclude:

- Implementation of a computer software tool can offer a teacher a medium in which to develop an *inquiry mode* of teaching. The demands of the tool can help a teacher to become more inquiring in teaching and stimulating inquiry among students as exemplified with Trude and Cabri. This is similar experience as reported by

Barzel who comments that such double challenges on teachers can be experienced "as a special opportunity to achieve their aims in terms of contents and processes" (Barzel, 2007, p.77).

- However, implementation of a computer software tool might be seen by teachers as an object in itself and inquiry experienced as an obstacle in efficient use of the tool in teaching requiring too much time spent on the tool. Inquiry might rather be something to implement in a later phase with the tool in teaching. This is evident from Jakob and Frode's argumentation of a progression for Cabri-use.
- Lack of clarity as to what inquiry means for teaching might prevent teachers' development and awareness of an inquiry mode of teaching. This was evident for Jakob and Frode who seemed to relate inquiry to the *nature of tasks* and students' *collaboration*. They argued for non-emphasis on inquiry because of the tasks they used which they did not consider to be investigative or problem solving tasks. They also referred to students' mainly individual work with Cabri as a reason why they did not consider their Cabri-use to have involved inquiry.

Although the nature of tasks and students' collaboration could promote inquiry, Jakob and Frode seemed to have neglected that inquiry more overall is characterised as a way of working and being. Jakob and Frode's interpretation of inquiry could have been stimulated by workshops in the projects. In the workshops, teachers worked with investigative tasks in group sessions used by didacticians to support inquiry among teachers. Inquiry is also a term difficult to translate to Norwegian language. Thus, these different reasons contribute to why inquiry was found hard to interpret for teachers despite their participation in developmental projects which emphasised promotion of inquiry.

With reference to the description of inquiry in the LCM project, I argue that Jakob and Frode had an emphasis on *inquiry as a tool in teaching* particularly related to the nature of tasks. In her orchestration, Trude tried to stimulate the students to raise questions, collaborate and discuss their achievements. Trude appeared to aim for *inquiry as a way of being* both in her teaching and among her students which indicates that an aim of the project was fulfilled. In the projects, teachers' development of inquiry as a way of being in teaching was an aim (Jaworski, 2004a). Indications of such a development is discussed in Jaworski (2007) in the following way: "So, developing inquiry as a way of being involves *becoming, or taking the role of,* an inquirer; becoming a person who questions, explores, investigates and researches within everyday, normal practice" (p. 127). Thus, Trude's arrangements and emphases seem to be a way to handle the suggested *double innovation* (see Section 7.2.1, p. 275) in the ICTML project: implementing Cabri and orchestrating Cabri-use in teaching by promoting inquiry as a way of being.

I end this section by considering consequences of students achievements with Cabri related to different role and interpretation of inquiry in teachers' orchestration. Jakob and Frode expressed great appreciation with their Cabri-teaching indicating that they considered their implementation and orchestration of Cabri-use as successful. They referred to improved achievements in geometry emphasising students' good test scores and efforts in Cabri-lessons. Jakob and Frode used expressions like "positive effect", "great efforts", "they loved it" and "good results by the unruly boys". Trude also referred to students' great efforts with Cabri. She argued to have observed *excellent learning* in her Cabri-lessons where students shared ideas, investigated Cabri and checked and compared their solutions utilising affordances in Cabri. I suggest the following conclusions:

- Teachers who promote inquiry as a way of being in teaching with a new computer software tool, emphasise students' efforts and achievements *during* their working phase with the tool.
- Teachers who consider inquiry being related to the nature of tasks and do not promote inquiry as a way of being in teaching with a new computer software tool, relate students' achievements to what students are able to do *after* the teaching has come to an end.

These conclusions also indicate a vital difference between teachers' *desired outcomes* and *goals* which are emphasised in Section 7.4.

7.3.3 Teachers' orchestrations of students' Cabri-use

In Sections 7.3.1 and 7.3.2 conclusions and implications of teachers' orchestration of Cabri-use were presented by offering a synthesis of the concepts *arrangements*, *emphases* in teaching, *teaching styles*, *teaching operations* and *inquiry*. In this subsection I give an overall perspective on teachers' orchestrations similar to that in Chapter 6: The theoretical perspective *instrumental approach* is utilised and I present conclusions and propose implications.

The instrumental approach emphasises the importance of teachers' orchestration of the two interrelated processes *instrumentation* and *instrumentalisation*. These are processes involved in students' successful use of a tool such as Cabri in mathematics teaching. In Chapter 3, I made a simplified description of these terms related to my research study (see Section 3.2.1, p. 74):

> I interpret *instrumentation* to be about getting to know what Cabri affords, how Cabri represents mathematical concepts and properties and development of abilities to use the tool. *Instrumentalisation* is about utilising and investigating in different ways the affordances offered by Cabri.

In Chapter 6 I concluded that Jakob and Frode mainly orchestrated students' *instrumentation* process with Cabri in their teaching. Over and over again both of them emphasised affordances in Cabri and students' development of successful techniques in Cabri which in Section 6.3.4 was argued being related to instrumentation of Cabri. Haspekian (2005) suggests that teachers who are newcomers with a tool in teaching typically emphasise the differences to ordinary tools and have big problems to exploit the tool in teaching. What she argues is basically that many teachers are struggling with supporting the instrumentation of the tool in mathematics teaching and consequently spend much time on the process:

> A teacher who is a ''non expert'' of the tool is poorly sensitised to the tool's potentialities. First, she/he sees some differences/added complexity, she/he is poorly prepared to combine instrumentation and mathematics learning and, for these reasons, she/he hardly gets any benefit from current resources (Haspekian, 2005, p. 137)

Comments from Jakob and Frode indicate that they experienced such complexity with Cabri. Frode argued that Cabri disturbed the students (see utterance 3, p. 204) and they both had a repeated emphasis on assisting students in development of successful techniques with Cabri. A consequence of this struggle could be the observed lack of emphasis on supporting students' instrumentalisation process with Cabri. Jakob and Frode prioritised to assist students with emphasis on the instrumentation process. Hence, these findings support Haspekian's claim.

I have argued that Trude orchestrated students' Cabri-use more *broadly* than Jakob and Frode where both processes seemed to have been supported. Trude held brief introductions in her lessons where she focused on techniques and affordances which I consider as orchestration of the instrumentation process. However, her main emphasis in the orchestration was on students' *instrumentalisation* process through support of students' collaborative and investigative efforts when utilising affordances in Cabri. Trude described a situation where the students collaboratively shared ideas and issues with the tool and investigated the tool. This is a description which seems to relate well to what Trouche (2005c) interprets as the key element in the instrumentalisation process. To conclude:

- In teachers' initial orchestration of a computer software tool in teaching, they often mainly support students' instrumentation process with the tool emphasising students' development of techniques and the tool's affordances.
- Teachers' emphasis on students' collaborative and explorative efforts can be helpful in order for teachers to orchestrate students' instrumentalisation process already in teachers' initial orchestration of students' work with a new computer software tool.

Based on these conclusions I propose the following implications:

- Teachers' emphasis on orchestration of students' instrumentation process could give good support of students' development of accurate use of techniques and affordances in software but little support on investigating mathematics with the tool. Such emphasis on students' development of techniques and affordances could have a positive effect on students' outcomes in tests especially if tests emphasise such aspects of tool use.
- Teachers' emphasis on orchestration of students' instrumentalisation process creates opportunities for students' use of Cabri as an investigating tool in their work with mathematics. However, as exemplified with Trude in my research, observations indicate that mainly her cleverest students were active or most active, and several of her students seemed to have slow progress with the tool.
- Development of an inquiry mode of teaching (see Section 7.3.2) could support a teacher to emphasise orchestration of students' instrumentalisation process with a new tool.

According to the instrumental approach, both students' instrumentalisation and instrumentation processes with tools are important in order for them to profit from use of the tools in mathematics teaching. Based on this awareness I pose the following question for further research:

1. What happens if teachers continue teaching with a computer software tool after some initial teaching where mainly only one of the processes has been given attention in their orchestrations of students' work with the tool?
    a. Will the emphasis on orchestration of the processes be different?
    b. What kinds of changes might be observed when the teachers get more experienced in using the software and use the software in teaching with another class?

I end this section by considering the question above based on a continuation of my own study of three teachers' implementation of Cabri. Trude's comments on her use of Cabri in the two subsequent years after her first ever use of Cabri in 2006, indicate that she maintained a similar teaching style and emphases in her lessons. In an e-mail response in January 2008, Trude commented on her teaching with Cabri in the new Grade 8 and 9 classes earlier the same month. She ended the e-mail by concluding that she dares to use Cabri, the students help each other and she develops as a "Cabri-teacher".

What is said (translation)	**What is said (original)**
…I dare to try and the students help each other. Each time I get a little bit better!! So Cabri is used here.	… Jeg tør å prøve og så hjelper elevene hverandre og for hver gang bli jeg litt bedre !! Så her brukes Cabri.

Event 43, Jan 17th 2008, Fjellet, Trude, e-mail responses, Audio, Episode 2

I consider Trude's comment: "Each time I get a little better", to indicate her own development of Cabri as an instrument and orchestration of students' work with Cabri alongside this. Assude (2005) found that teachers who used Cabri for the second time were able to make *time saving actions* based on experience the first year (see Chapter 2, p. 39). Trude's comment might indicate that she benefited as a Cabri-teacher based on such experiences although time was not brought up by Trude as in issue in the e-mail response.

Jakob did not continue using Cabri in his teaching. However, one year after his first ever use of Cabri in teaching, he used the DGS package GeoGebra in his new Grade 8 class, When I observed some of his lessons with GeoGebra, the teaching style, emphases and arrangements with GeoGebra seemed similar as with Cabri one year earlier. He was still using the teaching package although the package presented use of Cabri and not GeoGebra. Frode took a school leader position at another school during the autumn 2006 so he did not use Cabri or any other DGS package after his initial use of Cabri except for a brief repetition at the start of Grade 9 (commented on in Chapter 6, p. 239).

Hence, comments in these last paragraphs indicate few changes from teachers' initial orchestration of students' computer software use in teaching. I argue that this question should be given treatment in future research including concerns for how didacticians can support teachers in their further development of teaching after some initial use of a new tool.

7.4 With what goals do teachers at Grade 8 implement and orchestrate Cabri-use in mathematics teaching?

In Section 7.2, the conclusions highlighted teachers' motives for implementation of Cabri. These conclusions were made based on analytical findings in Chapter 5 where analysis of expansions of collective objects in activity system was used to illuminate teachers' motives. The objects and thus teachers' motives included emphasis on teachers' implementation of Cabri aiming for students' learning of geometry. Objects are personalised by teachers in actions energised by their *goals*. The relationship between objects and goals was phrased in the following ".. the goals are what the teachers wanted to achieve with this object such as students' successful 'techniques' " (see Table 3.1, p. 64). In Chapter 5, I also argued that teachers' expressed *desired outcomes* in the implementation process ahead of their use of Cabri in teaching indicated their goals. These desired outcomes were included in the representations of the activity systems (see Figures 5.1 – 5.3, p. 185-187).

Implementation and orchestration of Cabri-use aiming for students' learning of the geometry topic building on use of compasses seemed to have been a common object for all the three teachers in my study. However, their desired outcomes seem to have been different. Jakob and Frode's desired outcomes with Cabri included students' increased motivation and improved scores in tests, use of same tests and teaching package, and to convince colleagues to implement Cabri. Trude's desired outcomes were to dare implement and have priority on Cabri with inquiry to fulfil external expectations. Included in this, she very much wanted to experience that she and her students had a collaborative development. Thus, I conclude that the different focuses in teachers' desired outcomes indicate differences in their goals.

I also argue that the decisions teachers made in planning and when accomplishing their orchestration of Cabri-use in teaching and their emphases in teaching indicate what they wanted to achieve, their goals. Thus, findings from teachers' *implementation* process emphasised *desired* outcomes while findings and conclusions from their *use* of the tool in teaching indicate *achieved* outcomes. Together these different phases contribute to analysis of teachers' goals and were in Section 6.3.2 utilised in the analysis related to Leont'ev's second level of activity, actions ↔ goals. Based on the findings from analysis of teachers' goals for implementation and orchestration of Cabri-use, I propose the following conclusions:

- Indications of teachers' goals are visible in the kinds of actions they want to support and observe from their students. This might either be students' actions when working with the tool, students' achievements with the tool in tests or both. In my study, Jakob and Frode emphasised achievements in tests *after* teaching while Trude emphasised students' achievements *during* their work with the tool.
- The external influence on teachers' motives, such as statements in National Curricula and didacticians' emphases in developmental projects, is evident. Teachers' goals and orchestration of teaching are personally adopted and less externally influenced.
- Teachers' goals for students' work with a new computer software tool seem to be stable through teachers' implementation phase to their later orchestration of the tool's use in teaching even when the tool is new for the teachers.
- There is not a clear coherence in a teacher's motives and goals. This confirms arguments in activity theory that objects are shared by a community of persons in an activity system but personalised as goals for actions.

7.5 What the thesis offers

I end this thesis by highlighting what I suggest as its most important contributions. In Section 7.5.1, I briefly summarise the thesis's overall contribution and offer some further implications for didacticians and the role of developmental projects. Section 7.5.2 is devoted to teachers where findings presented earlier in the thesis are reformulated with the aim to communicate with teachers. The section illustrates and discusses the two main kinds of implementation and use of a new computer software tool found in my study, and is based around contribution related to three questions considered relevant for mathematics teachers more generally:

1. How can teachers manage to accomplish the teaching with a computer software tool which they and their students never have used before?
2. What benefits can students gain from approximately 20 hours with initial Cabri-teaching and how might this be documented?
3. What was important in order for to be able to implement Cabri as a new computer software tool?

The thesis ends with some closing remarks (7.5.3).

7.5.1 Contributions to researchers and policy makers

This thesis has contributed with findings, conclusions and implications related to two research questions which consider teachers' motives, goals and their initial orchestration of the use of a computer software tool in mathematics teaching. Conclusions indicate that although teachers might have similar motives, teachers' implementation processes differ and in particular their goals and their orchestration of the new tool in teaching differ. Conclusions also pinpoint that the use of a new computer software tool in teaching was worthwhile and that teachers experienced improved achievements in mathematics by their students compared to not using the tool.

What this thesis in particularly does is to consider teachers' implementation and use of a new computer software tool in relation to requirements for such use from policy- and curriculum makers and external support by didacticians in developmental projects. Conclusions in Section 7.4 highlight that the external influence is evident on teachers' motives. Conclusions pinpoint that developmental projects and didacticians in the projects guide and give expectations regarding teachers' priority for development like the proposed use of Cabri in an inquiry way. However, external efforts to influence teachers' orchestration of Cabri-use, by indicating how to use the tool in teaching, are less successful because teachers' orchestration are related to their goals which are personally adopted and consequently difficult to exert an influence on.

In the rest of this section I suggest further implications for the role of developmental projects in promoting teachers' development in teaching. In particular, I consider teachers own development work and the sustainability of development in teaching at schools. Involvements of several mathematics teachers, and at least one school leader at each school, and work together for several years were seen as important in order to have sustainable development at schools. The latter is being substantiated below with reference to my own study and experience from a new ongoing developmental project where teachers at Austpark participate.

Analytical findings in the thesis emphasise Jakob and Frode's experienced success to include Eivind, the third mathematics teacher at Grade 8 on Austpark, to use Cabri despite Eivind's non-participation in the developmental projects. Hence, teachers within the developmental projects managed to involve a teacher at the school outside the project. Use of DGS was followed up at the school the year after with a new DGS package and also by four other mathematics teachers at Austpark after both Jakob and Frode had ended their teaching career at Austpark. Thus, at Austpark, Jakob and Frode's efforts led to a sustainable development in mathematics teaching at the school. Trude's single initiative did not have the same sustainable consequence at Fjellet apart from herself. I substantiate the claims in this paragraph by considering two more episodes from my study.

The teachers at Austpark mentioned the creation of a school team with four teachers to be an important outcome from their participation in developmental projects. This group was after a year extended with Jakob. In fact, independent of the developmental projects three of the mathematics teachers at Austpark had formed a team of mathematics teachers half a year ahead of the projects. This indicates a readiness for such collaboration at Austpark. Teachers' work in school teams was one of the desired outcomes didacticians in the LCM project wanted to support as illustrated in Chapter 5 (see Figure 5.1, p. 185).

In the LCM/ICTML focus group interview in March 2006, Jakob and Gunnar highlighted advantages with a school team with mathematics teachers (see Appendix 8xxxvii, p. 356). Jakob emphasised how he as an inexperienced teacher has valued the possibility to talk about his teaching experiences within a community of mathematics teachers. Gunnar expressed that he regarded the number of teachers as crucial for being stimulated and a well-working group. He regarded the entrance of Jakob which increased the group from four to five as an improvement both because of an increase in the number of teachers and Jakob's competences. Thus, this pinpoints that the number of teachers in a school team and support from school leaders at a school contribute importantly to development in teaching. This supports a claim in Monaghan (2001) that more focus should be given to how *the school structures* allow for development in mathematics teaching.

At Fjellet, Trude was involved in both developmental projects until she ended her participation and had a break from March 2006 until August 2006 (see Chapter 4). One of the two other mathematics teacher at

Grades 8-10 at Fjellet, Markus, was also involved in the developmental projects. The third mathematics teacher at Grade 8-10, Ludvig, only took part in two workshops and a few meetings. Apart from two school team meetings with these three teachers, initiated by didacticians in autumn 2005, collaboration in planning and teaching between the three mathematics teachers at the lower secondary grades was not evident at Fjellet. They also participated in school team meetings related to the LCM project which included up to 6 mathematics teachers from Grades 1-10. Despite these meetings, the school team with mathematics teachers at Fjellet seemed not to work with the same effect as the team with mathematics teachers at Austpark. The number of mathematics teachers in respect to the span of grades at Fjellet and several mathematics teachers at each grade at Austpark were probably important reasons for this difference in ongoing development and work of school teams at Austpark and Fjellet. Such concerns were raised by Markus in the LCM/ICTML focus group interview in response to expressed problems with collaboration between the mathematics teachers:

Ut	Who	What is said (translation)	What is said (original)
15	Markus	For my concern it was also the situation that people are sitting a bit on their own; it is a 1-10 school. Then there is one teacher, like it is at the lower secondary school, at each grade, and a lot of us have problems to manage working together because each of us have our own things and do not see that potential to gain anything from others.	For mitt vedkommende, så var det også sånn at man sitter litt alene på en sånn skole som dette; det er en 1-10-skole. Så sitter det en lærer sånn som i ungdomsskolen på hvert trinn, og mange av oss kan være litt vanskelige og så få jobbet sammen, for hver sitter med sine ting og så ser de ikke at det er noe å få hos andre.

Event 34, Mar 23th 2006, Fjellet, LCM/ICTML interview, Audio, Episode 1

Near the end of the LCM and ICTML projects, schools were asked whether they wanted to be part of a new developmental project, the TBM[31] project. Austpark wanted to continue their participation, this time

[31] The TBM project is supported by the Research Council in Norway (NFR no. 176442/S20) and is managed by didacticians at UiA. TBM is an abbreviation for “Teaching Better Mathematics”. The TBM project is based on collaboration between didacticians and teachers, pre-school teachers and leaders in two local councils and the local county where UiA is situated. TBM gives funding for research and didacticians’ work to promote development of teaching in schools while another project named LBM gives funding to support school teachers’ and pre-school teachers’ development of mathematics teaching included participation in workshops arranged by didacticians at UiA. LBM is a shortening for “Learning Better Mathematics” (“Lær Bedre Matematikk”). The LBM project is supported by the Competence Development Fund of Southern Norway (http://www.kompetansefond.com/english) and the local county, and is managed as a unity with the TBM project from 2007-2010. At another level, TBM also involves collaboration within a consortium with didacticians at UiA and four university colleges in Norway.

with all 9 mathematics teachers involved, while Fjellet did not want to go on in a new collaboration with UiA and the TBM project. Fjellet had applied the Department of Education for funding of a school development project but did not succeed in getting support. This decision came ahead of the final year of the LCM and ICTML projects and influenced their decision not to participate in the TBM project and with only two teachers in the final year of the LCM and ICTML projects.

The analytical findings above and earlier conclusions stress the importance of didacticians' and teachers' ongoing work and involvement for many years. These are arguments for founders, policy makers and school leaders to support such projects acknowledging that development takes time. I believe that the complex process of having sustainable development in mathematics teaching should be considered evolving within the *group* of mathematics teachers working at a grade or across grades in each school.

7.5.2 Contributions to mathematics teachers considering initial use of computer software tools in mathematics teaching

This thesis illuminates how three teachers implemented and used for them a new computer software tool in mathematics teaching at Grade 8. By a teacher's 'implementation' I mean the process a teacher undergoes from first being introduced to a new computer software tool for teaching, decided to use the tool in teaching and what the teacher did in order to prepare and be able to use the tool in teaching. The tool being studied in this thesis is the DGS package Cabri.

The thesis gives extensive treatment of three teachers, Jakob and Frode at Austpark School and Trude at Fjellet School who participated in two developmental projects aiming for development where inquiry[32] and use of computer software tools in mathematics teaching were central. The teachers in the study addressed issues and made experiences in their implementation process of Cabri and when using Cabri for the first time. These issues and experiences are argued to be germane to *other* teachers facing the same or similar National Curriculum requirements, and who consider using a piece of computer software package for the first time and in particular if they consider using Cabri or another DGS.

In addition to the general requirements for use of computer software in the National Curriculum in Norway, use of Cabri and other kinds of DGS in mathematics teaching have also elsewhere been given some attention in Norway. Several articles in a journal for mathematics teachers in Norway, Tangenten[33], and sessions at the yearly national gatherings

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[32] Inquiry has now official Norwegian translation but ”spørrende” and ”utforskende” approach was used as translation in the projects

[33] Information about the journal ”Tangenten” is available on: http://www.caspar.no/tangenten.php

for mathematics teachers at the Norwegian Centre for Mathematics Education have focused on DGS and often Cabri. A number of mathematics teachers in Norway have started to use DGS and many teachers potentially consider use of DGS in mathematics teaching. The requirements in the National Curriculum concerning integration of computer software in mathematics “wherever suitable” give implicit support for spending time on DGS. However, use of DGS has not yet been followed up in the National Examination in mathematics at Grade 10, apart from an optional spreadsheet part of the examination. With this background, I argue that findings from other teachers’ struggles, efforts and decisions when implementing and using Cabri offer insights worthwhile for many teachers.

Although Jakob and Frode implemented and used Cabri differently compared to Trude, all three teachers considered their implementation and use of Cabri as successful with a great learning outcome for their students. These differences are outlined on the following pages around the three numbered questions introduced on page 290 which this thesis contributes with answer to. This section ends with a brief discussion of benefits and disadvantage with the ways the three teachers implemented and used Cabri.

1. How can teachers manage to accomplish the teaching with a computer software tool which they and their students never have used before?

It is demanding to prepare and start to use a computer software tool which is new both for the teacher and the students. With an exception for Frode who had a number of teacher students available in some of Cabri-lessons, he and the two other teachers were alone as teacher in their classes with 20-25 students. This frame creates challenges in respect to teachers’ accomplishment of teaching being able to give sufficient support to the students during their use of the tool. In Table 7.1 I have listed some characteristics concerning how the teacher in my study accomplished these challenges:

Table 7.1: Characteristics concerning accomplishment of lessons with Cabri when used initially as a tool in mathematics teaching

	Jakob and Frode	Trude
Working method, available room and equipment	Most of Jakob and Frode’s Cabri-teaching occurred at a computer lab where the teacher’s computer was attached to a video projector. The teachers also used laptops in their classrooms a few times. Frode had two classes and in his classes the students used one computer each, while in Jakob’s class students worked together two by two.	Trude’s Cabri-lessons occurred in a classroom where half the class worked with Cabri on one laptop each. The other half worked with other mathematics tasks without any use of ICT. The two halves exchanged after 45 minutes. Portable video projectors were available but not used by Trude.

Tasks and teaching packages	Jakob and Frode used a pre-made teaching package in most of their Cabri-lessons. The package consisted of worksheets with instructions for students supposed to fit a 45 minute lesson at Grade 8. The worksheets treated classical constructions, such as 60 and 90 degrees angles and perpendiculars, as well as other menu options in Cabri for example labelling points and lines and calculation of angles. Appendix 2 contains copies of the three first worksheets.	In Trude's lessons, tasks were presented on a flip-chart without any further line of action. An example of the content in one such flip-chart was presented in Figure 6.8 (see p. 247).The geometrical elements treated in the different Cabri-lessons were similar as in Jakob and Frode's lessons, as well as tasks where students were asked to make different stars and find symmetry axes.
Main emphases in teaching	Jakob and Frode emphasised that the students' were able to construct successfully with Cabri. Much time was used on the difference between drawing and constructing with Cabri, and the dynamic dragging-function in Cabri was introduced as a verifier whether a construction was successful. For example: if an angle still was 60 degrees after dragging in one of the sides of the angle, the construction was verified as successful.	In the first part of lessons with Cabri, Trude wanted her students to find ways to accomplish the tasks, and as for Jakob and Frode the tasks were often about construction with Cabri. Most of the time in lessons was earmarked to students' investigation of possibilities with Cabri, in particular the dynamic dragging-function, and that the students compared and found, for example different ways to construct a figure.
Teacher's and students' roles in Cabri-lessons	The students worked with the tasks in the worksheets. Jakob and Frode assisted the students when needed, and presented line of actions with Cabri in plenaries with the help of the video projector. The teachers' contributions in plenaries typically occurred as brief introduction to lessons and during lessons if several students had problems with Cabri. In their contributions, the teachers emphasised where to find and how to use menu options in Cabri. When assisting students individually, the teachers pointed and traced with the fingers at students' screen and occasionally took over the computer mouse in order to get students' attention.	Trude accomplished brief oral introduction and summing up before and after students working period with Cabri in the lessons. During the work with Cabri, students worked with the tasks and Trude assisted the students. She asked the students to help and present for each other their achievements. Like Jakob and Frode, Trude pointed at students' screen with her finger and in addition used words such as "there" and "a little to the left" to help the students in their use of Cabri.

Enter-prises to ease students' work with Cabri	The students worked with the same mathematical content in subsequent lessons with compasses and Cabri. Jakob and Frode argued that this progression was time economical. For example in lessons where they first worked with a construction using compasses and explicitly mentioned how students could do the similar construction with Cabri afterwards. Jakob and Frode also argued that their use of the teaching package led to less need for follow-ups from the teachers compared to not being used.	The students worked with the same mathematical content in Cabri-lessons treated with compasses weeks earlier. Trude argued for this progression as crucial in order for her students to work with Cabri without any kinds of written lines of actions and with limited need for assistance from her as their teacher.

2. What benefits can students gain from approximately 20 hours with initial Cabri-teaching and how might this be documented?

All the three teachers considered their students' achievements with Cabri as good and successful. Below in Table 7.2, I have listed what the teachers considered as good and successful and what they considered as important if they continued to use Cabri in the same classes later.

Table 7.2: Students' outcome from initial use of a computer software tool such as Cabri

	Jakob and Frode	**Trude**
What were considered successful with the use of Cabri?	Jakob and Frode emphasised that their students' working efforts in Cabri-lessons had been great. Use of Cabri in addition to compasses had also contributed to improved achievements in geometry on the school's year examination in mathematics compared to earlier years. Their students also achieved well at a Cabri-test and in a test in the classes at the start of Grade 9.	Trude emphasised what she several times expressed as enormous working efforts by her students in Cabri-lessons. She pointed to how enjoyable she had experienced their collaborative and investigative work with the tool. Trude did not accomplish tests with Cabri and thus did not substantiate her claim with reference to achievements in tests.
What would teachers emphasise in a later phase with Cabri?	Jakob and Frode argued that it was essential that students first got experience with Cabri before they in a later phase could spend time to investigate the tool and work with more open-ended task.	Trude wanted to continue in a similar way the work in her class, where her students together with herself investigated more possibilities with Cabri.

Jakob and Frode designed the Cabri-tests themselves. They first made and accomplished a test immediately after their Cabri-teaching came to an end (see Appendix 5c), and later they also made a task which was included in the year examination test in mathematics at Grade 8 at Austpark. Both tests were accomplished in all four classes at Grade 8 and included one class they were not teaching since Frode taught two and Jakob one Grade 8 classes. By the use of these tests, Jakob, Frode and the third mathematics teachers at Grade 8, Eivind, could formally test whether the students were able to accomplish construction and utilise other possibilities with Cabri.

Trude did not accomplish any kind of formal testing with Cabri. This difference in emphasis on testing was expressed by the teachers as a desired choice. Jakob and Frode repeatedly argued that to design and use tests with Cabri was vital for their decision to use Cabri in teaching, while Trude rather emphasised the importance of starting to use Cabri and experience students' work and utilisation of the tool.

3. What was important in order for to be able to implement Cabri as a new computer software tool?

An obvious condition for use of Cabri or any kinds of computer software tool is access to the tool at the school. Cabri is licensed, and for the teachers at the two schools considered in this section Cabri had been bought and installed at the schools' computer lab and portable computers. In addition, a number of other issues needed to be addressed before the teachers could start to use Cabri in teaching. Jakob and Frode worked at a school with four classes at each grade while Trude's school only had one class at each grade. This difference in number of classes at a grade influenced the kind of issues teachers met and emphasised in their implementation process of Cabri. In Table 7.3 I have listed teachers' issues and how they coped with them in their implementation process

Table 7.3: Issues in implementation process of Cabri as a new computer software tool

	Jakob and Frode	Trude
Regulations for teaching and their consequences for the use of a new computer software tool in teaching	Mathematics teaching at Austpark School was regulated on rules that all students at a grade got a similar teaching in mathematics and simultaneously used the same tests reflecting the teaching. Consequently, implementation of a new computer software demanded that all mathematics teachers at a grade wanted to use the tool in teaching and accomplished tests with the tool. The use of a common teaching package was expressed as important in the inclusion process of more teachers. Thus initiated by Jakob and Frode, implementation of Cabri became a common effort for the mathematics teachers at Grade 8.	Trude could, as the school's only mathematics teacher at Grade 8, make changes in her teaching which did not directly influence the other mathematics teachers. She did not have to follow any regulations concerning testing of students' outcomes after using a new tool in teaching. Thus, implementation of Cabri was a personal choice and challenge.

Reserve extra time on the geometry topic	All the mathematics teachers at Grade 8 at Austpark needed to reserve extra time on the geometry topic since Cabri would demand more time spent on geometry in teaching as well as more time for preparation.	Trude needed to reserve extra time on the geometry topic since Cabri was new both for students and the teacher.
Access to computers	The teachers had to book the computers and computer lab early in order to have access to computers. Such early bookings limited the possibilities of changes during planning of lessons, but were expressed as having an effect of throwing themselves into emphasis on the new tool.	Access to computers was not experienced as problematic for Trude. Trude used portable computers which were available on the Fridays Trude wanted to use them.
Design and use Cabri-tests	Jakob and Frode designed and used tests supposed to check students' abilities to accomplish constructions and other options in Cabri successfully.	Not an actual issue for Trude.
Use of Cabri despite students' lack of free access to Cabri at home and lack of testing DGS skills in national examination	Jakob and Frode considered it as a big issue that the school's license for Cabri did not cover students' potential use of Cabri at home. This issue was solved the following year when the teachers implemented and used the free DGS tool GeoGebra instead of Cabri. The teachers expressed frustration about lack of testing students' abilities with DGS in the national mathematics examination in Norway at Grade 10. However, this issue was obviously not addressable for the teachers but they hoped that their students would be able to achieve better in geometry with compasses which was tested in the examination.	Not emphasised by Trude.
Dare to use Cabri in mathematics teaching	Not emphasised as an issue by Jakob and Frode except to stimulate other mathematics teachers at the school, and particularly at their grade, to use Cabri.	Trude paid much attention to the importance of daring to use Cabri in teaching, despite her own expressed lack of confidence with computer software tools and in supporting students in their work with such a new tool in teaching.

Benefits and disadvantage with the two illuminated ways to implement and use Cabri initially in teaching

Tables 7.1 – 7.3 present two rather different implementation processes and ways of using a computer software tool for the first time in teaching. Trude exemplifies a situation where a teacher is free to make changes and use a new computer software tool in teaching provided the tool is available at the school's computers. As it is evident from Table 7.3, this freedom influenced her implementation process and the kinds of issues she expressed as important. Her issues were typically personal and about whether she dared to use the hew tool in teaching. Jakob and Frode's school had regulations which they needed to take into account in order to use a new tool in teaching. Consequently their implementation process was to a larger extent characterised by issues with an overall focus that all mathematics teachers on a grade used the new tool and that they had to take responsibility to design and use tests which tested students' abilities to utilise the tool. These teachers also had much focus on the new tool's positive influence on students' abilities to use compasses which traditionally have been tested in the Norwegian national examination in mathematics. For Trude, it was the use of Cabri itself and students' working process and experience which were the most important.

Jakob and Frode did emphasise that their collaborative implementation and use of Cabri had been enjoyable and led to sustainable development of mathematics teaching at the school since other mathematics teachers used Cabri or GeoGebra the following year. Although Trude could start using Cabri more independently, she was also more left to her own. Like Jakob and Frode, Trude had the special opportunity of participation in developmental projects where she could discuss and present her use of Cabri and which she expressed as vital for her implementation of Cabri. This is obviously not a possibility teachers often have and indicates the importance of collaboration in order to stimulate development and sustainable development in teaching at a school.

The freer situation for Trude seemed to have made it easier for her than for Jakob and Frode to stimulate use of Cabri in an investigative way as it was phrased in the national curriculum or with an inquiry as it was stated in the developmental projects. The regulations at Austpark, including Jakob and Frode's enterprises with a teaching package containing instructions for students and tests, made it more difficult to emphasise investigations and inquiry ways of working which they rather considered in a later phase with Cabri in teaching.

Based on the features described above, I argue that the two illustrated ways of using the new tool should be seen in respect to different natures of schools and existing regulations for use of new computer software tools. When Trude felt ready, she could start to use Cabri without any further particular hindrances. On the contrary, Jakob and Frode had to take the school's co-ordination and testing regulations into account. They had to work to convince the final mathematics teacher at the grade to use Cabri, consider possibilities with tests and to design tests, and spend time to find and decide on using a teaching package which would guide students' work with the new tool and support teachers' use of the new tool in teaching.

Findings illustrate that the students seemed to have gained from both the illustrated ways of using Cabri. Jakob and Frode's students achieved well both on constructions with Cabri and compasses. Trude's students got more experience with investigation with the tool than Jakob and Frode's students, but some of the students in Trude's class had more limited abilities to accomplish constructions. It is important to consider the initial use of a tool like Cabri in light of a potential further use of the tool. For students who have had the kind of focus in teaching that Jakob and Frode had, more experience on investigations with the tool could contribute to their achievements with investigation of mathematics. Students who meet the kinds of emphasise in teaching Trude had, could benefit from further training in using the tool and at the same time further emphasise investigation of mathematics with the tool.

Finally I want to emphasise that this thesis has illustrated two main ways of implementing and using Cabri as a new tool in mathematics teaching. Obviously other ways exist and might be worthwhile and I hope teachers can find their ways of using the tool, and that other studies can contribute with further findings.

7.5.3 Final words

This thesis has suggested contributions to researchers, policy makers and teachers concerning implementation and use of computer software tools in mathematics teaching. As emphasised in Chapter 4, conclusions from a case study should be treated with caution in respect to implications and generality. However, the findings and conclusions also have potential to " pinpoint critical processes and identify common phenomena" which later can be found to be "germane to a wider variety of settings" (extracts from a quote from Delamont and Hamilton (1993) presented in Chapter 4, p. 92). Thus, what I have done in this thesis is to propose contribution to the "wider variety of settings" from which I hope other researchers, policy makers and teachers can benefit.

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Appendices 1-8

Appendix 1 Chronological overview of events in the case

Ev[34]	Date/type/who	Headlines and examples	Data[35]
1	26.01.2005 ICTML-WS3: Trude, Harald, Gunnar, Markus	Reflection on Cabri and possible implementation of Cabri in teaching after working on Cabri for the first time in the ICTML project. Trude commented about teachers' own tool skills, fun to work with Cabri and a critical need of access to Cabri at the school. Harald emphasised possibilities offered by Cabri mentioning quick checks and verifications by help of the dynamic dragging-function. He highlighted a need for more time to improve own tool skills. Markus concerned for time, students' motivation and importance of good tasks when using ICT	vi, no Total: 120 min DR: 25 min TR: 25 min
2	20.04.2005 ICTML-WS4: Trude Gunnar, Markus	Reflection after working with help of Cabri and Excel. Gunnar and Trude about Cabri competence and development. Trude compared her own and students' development. Gunnar about resistance to Cabri in his school. Discussion on what the mathematics looks like when using Cabri. Markus about students' roles and learning when collaborating.	vi, no Total: 120 min DR: 73 min TR: 8 min
3	28.09.2005 E-mail from didacticians in the ICTML project	A mail sent out the evening after ICTML Workshop 5 where Aud wrote that she, Otto and Ingvald wanted to come to schools to meet the teachers in the ICTML project and preferably one of the school leaders. She indicated agenda for the meeting: *"We want to discuss status in the ICT project at the school and plans for development"* (translated to English)	Copy
4	14.10.2005 Letter to vice principal at Austpark concerning LCM and ICTML projects	Letter to the vice principal at Austpark from the project leaders of the LCM and ICTML projects. The letter emphasised issues in relation to the school's fulfilment of contract in the projects and requested a meeting at the school. On the following day, the meeting was scheduled and held on the 4th of November (see Event 9).	Copy
5	24.10.2005 School team meeting: Trude, Markus, Ludvig, Principal, Aud, Otto, Ingvald	School team meeting requested by Aud, Ingvald and Otto for the ICTML school team at Fjellet (see Event 3). Overall planning for utilising ICT in mathematics classroom. Otto would contribute in carrying out some lessons with ICT and the teachers planned to observe and participate.	au, no Total: 50 min

[34] Abbreviation: Ev =Event. The events are numbered chronologically (1, 2, …, 44)
[35] This column contains information about types of data. Abbreviations used: au = audio, vi = video, no = notes, DR = Data reduction, TR = transcription, min = Minutes

6	26.10.2005 School team meeting: Frode, Jakob Harald, Gunnar, Elise, Vice principal, Otto, Aud, Ingvald	School team meeting requested by Aud, Ingvald and Otto for the ICTML school team at Austpark (see Event 3). About follow ups concerning the ICTML project. About organising issues (rooms available) and access to software. Jakob informed that he planned to use Cabri in his class after Christmas. A workshop session with Cabri led by Otto for all teachers at Austpark decided (see Event 13).	au, no Total: 95 min DR: 76 min TR: 11 min
7	27.10.2005 KUL meeting: Didacticians at UiA	A meeting to plan a later meeting with school leaders. Concerns for project commitments.	au, no Total: 118 min DR: 118 min TR: 2 min
8	27.10.2005 E-mail from Harald to didacticians in the ICTML project	In the e-mail Harald informed about time for a school team meeting and a workshop session scheduled after the school team meeting the previous day: A two hours school team meeting on the 7th of December (see Event 12) and a two and half hours workshop session on the 14th of December (see Event 13). Harald described the suggested content of the second meeting in the following way: "On the final Wednesday Otto comes to assist us in making a "start plan" for Cabri."	Copy
9	04.11.2005 School team meeting: Frode, Jakob Harald, Gunnar, Elise, Vice principal, Eli, Aud, Ingvald	School team meeting concerning Austpark's further work in the LCM and ICTML workshop. The meeting was requested by didacticians at UiA based on concerns about school's fulfilment of contract. A letter had been sent in advance to the school on the 14.10.2005 (see Event 4).	au, no Total: 45 min
10	07.11.2005 School team meeting: Trude Markus, Ludvig, Otto, Ingvald	School team meeting to plan use of ICT in mathematics classroom. Which topics and tools? Decision: Focus on spreadsheet: investigate number squares, average temperature, "Trim"-task (statistics) and Mobile phone-task. Otto would contribute in carrying out the lessons; the teachers expected to observe and participate.	au, no Total: 90 min
11	01.12.2005 KUL meeting: About work in schools: Didacticians at UiA	In the meeting, didacticians shared their experience from work with schools the first 1 ½ year of the projects. Ingvald reported from Austpark where Aud and Eli commented the letter (see Event 4) and meetings at the school (see Events 6 and 9)	au, no Total: 139 min DR: 139 min TR: 3 min

12	07.12.2005 School team meeting: Frode, Jakob Harald, Gunnar, Elise, Aud, Otto, Ingvald	In the school team meeting Frode considered priority on modern tools. Jakob emphasised use of Cabri to support a greater engagement for mathematics outside school. They both talked about their plans for Cabri-use in January 2006 where they had decided to use a written teaching package. Harald highlighted that use of Cabri was a pedagogical choice	au, no Total: 65 min DR: 65 min TR: 4 min
13	14.12.2005 Workshop session at Austpark: Frode, Jakob (Harald, Elise, Gunnar, 7 other teachers including the ICT leader, Principal, Aud, Otto	Workshop session for use of Cabri at Austpark held by Otto (Ingvald not present). In her notes, Aud commented that the session mainly emphasised development of teachers' competence in using Cabri. Not a "start-plan" for implementing Cabri at Austpark as indicated by Harald (see Event 8).	au, no Total: 120 min
14	10.01.2006 Classroom visit Compasses: Jakob	The lesson emphasised use of compasses to accomplish geometrical constructions.	au, no Total: 45 min
15	10.01.2006 Computer lab visit, Cabri: Jakob	Use of Cabri, Jakob orchestrates and intervenes. Use of a written teaching package designed by Henning Bueie.	au, no Total: 45 min
16	11.01.2006 LCM-WS10 Group session: Frode, Trude, Jakob, Harald, Otto, Ingvald	A conversation based on experience of using Cabri - a group of teachers at Austpark and Trude at Fjellet had started to use Cabri and talked about their experiences so far. Frode considered their Cabri teaching and their colleagues' tools skill development. Trude reported from her first Cabri lesson and her plans for use of Cabri most weeks until Easter. Students were able to make points, lines, circles, constructed equilateral triangle and perpendicular by help of circles. She experienced students' work and the whole effort as fun, the students sat with their computer, some managed it and presented their achievements to others. She argued that this gave excellent learning.	vi, no Total: 120 min DR: 29 min TR 15 min
17	17.01.2006 Classroom visit, Cabri and other tools: Jakob	A two hour lesson on Cabri. Use of teaching package with worksheets developed by a former colleague of Jakob in the master programme at UiA. Use of Cabri: construction of 60 and 90 angles. Angle bisector. Students' tool mistakes led to interventions by the teacher.	vi, no Total: 90 min DR: 8 min TR: 1 min

18	18.01.2006 Classroom visit: Ruler and compasses: Frode	Use of compasses. After a short introduction with some practical things concerning his class, Frode in plenary presented "Four things" supposed to be the focus of the day: About construction of bisectors by compasses.	au, no Total: 26 min DR: 22 min TR: 4 min
19	18.01.2006 Computer lab visit, Cabri: Frode	A lesson on the computer lab where students in one of his classes for the fourth time used Cabri. The content was similar to what they did with compasses in the previous lesson (see Event 18). Frode introduced the Cabri session by saying: "*We do it together*". Frode presented by use of the video projector and the students were supposed to do the same on their PCs (one by one). Construction a) was carried through (bisector to a point on a line). After a short break, Frode carried on together with his students and made b) bisector to a line and c) bisector through a point outside a line. In addition, the students were allowed "to play" for some minutes with the tool.	au, no Total: 60 min DR: 10 min TR: 4 min
20	18.01.2006 Conversation after lesson: Frode	A brief conversation with Frode just after lessons with use of compasses and Cabri (see Events 18 and 19). Frode emphasised that he steered the activity because of a difficult class. He had decided not to use the teaching package designed by Henning Bueie in this lesson. Frode emphasised use of words covering how to use the tool and why, such as keeping the compasses length, vertex and paying attention to appearing text like "Through this intersection point".	au, no Total: 5 min
21	18.01.2006 ICTML-WS7: Trude, Jakob Gunnar, Markus	In the workshop, the teachers reported from activity in schools. Jakob commented his use of Cabri. He emphasised students' use of imprecise techniques in Cabri (see also Events 15 and 17). About students' reaction to use of Cabri and some problems with students tool skills (ability to utilise Cabri in intersection points, e.g. circle/point). Trude commented from her Cabri teaching similar as in Event 16, and reported enthusiastically about one student who showed great progress using Cabri. Markus presented experiences from the computer lab session at the workshop and reflected on potential use of an own made application in his class. He wanted discussions among students since they create reflections, engagement and inspiration for further work.	vi, no Total: 120 min DR 82 min TR 19 min

22	20.01.2006 Classroom visit, Cabri: Trude	Trude accomplished a Cabri lesson (her second ever) mainly considering construction of triangles. The tasks were presented on a flip chart. Teacher-student interaction in working phase. Summing up session in the classroom led by Trude.	vi, no Total: 90 min DR: 16 min TR: 9 min
23	20.01.2006 Conversation after Cabri-lesson, Trude	A brief conversation just after finishing the Cabri session in the classroom (Event 22).	au, no Total: 8 min DR: 8 min TR: 3 min
24	25.01.2006 Classroom visit, Ruler and compasses: Frode	A session with a review of a geometry test with construction tasks where students had used compasses. Dialogue between Frode and some few students. Frode sometimes utilised teaching operations similar to the approach in Cabri but did not mention it explicitly in this session. After a break, Frode carried on with construction of more “difficult angles” such as 67,5 and 32,5 degree.	au, no Total: 90 min Notes:
25	07.02.2006 Classroom visit, Cabri: Jakob	This session included a review of a Cabri test students had accomplished some days earlier. Jakob stood upfront close to the video screen pointing with his finger at the image while on of his students accomplished the constructions. In his orchestration Jakob emphasised tool skills (For example: How to use the mouse pointer to secure that lines/circles go through points) and the dynamic dragging-function as a verifier. The review included review of constructions of perpendiculars and angle bisectors.	au, vi, no Total: 45 min DR: 8 min TR: 3 min
26	07.02.2006 Computer lab visit, Excel: Frode	This was the second lesson in Excel for these students following after the period of work with Cabri. In the session students were working with Excel. The video contains recording of some students work with Excel and a plenary intervention by Frode. In the lesson students used a teaching package by Henning Bueie.	vi, no Total: 45 min
27	07.02.2006 Conversation, Cabri: Frode	A brief conversation immediately after a lesson in Excel at the computer lab (see Event 26). Frode reflected on his and Jakob’s experience after using Cabri, especially problematic issues in relation to how they had used Cabri in their teaching.	au, no Total: 3 min TR: 3 min

28	15.02.2006 Computer lab visit, Cabri and Excel: Frode	The data reduced part of the lesson is from a review of a Cabri test led by Frode (same test considered in Jakob's review in Event 25). Frode emphasised how to accomplish the constructions, to "hit" the proper point with the mouse pointer, the number of score points and how to check whether or not a construction was correct (the dynamic dragging-function used as a verifier). In the rest of the session students carried on with Excel using the same teaching package as in the lesson 8 days earlier (see Event 26).	au, no Total: 45 min DR: 12 min TR: 12 min
29	21.02.2006 Computer lab visit, Excel: Jakob	The video recording from this session includes two of the students' design of a budget with balance and formatting in Excel. The recording shows how the teacher intervened into students' operations with Excel with several inputs that the students were supposed to follow up in their work.	vi, no Total: 90 min DR: 41 min TR: 3 min
30	22.02.2006 LCM-WS11 Group session: Jakob, Frode, Trude Harald, Aud, Ingvald, Otto	Conversation about Cabri teaching on Grade 8 at Austpark. A focus on students' motivation, tool skills and a lack of inquiry-focus. Jakob and Frode sketched their suggested progression: Tools skills and then inquiry followed by a discussion concerning its suitability. In the group session, didacticians responded by questioning what inquiry could look like and are about. Frode reported from his Cabri teaching and the interaction in the classroom. Trude reported from a Cabri lessons in her class, she focused on her non-use of teaching packages (she only listed the tasks on a flip chart) and considered inquiry in regard to Cabri. She argued that her students worked enormously well with tasks in Cabri which she experienced as great to observe. She did not want to stop them, but intervened challenging them to consider if they could have more and different solutions etc. She argued that her students reached further than herself and were more willing to test out things. Trude commented the difficulty of the word inquiry and the difficulty of promoting mathematical conversations in the classroom.	vi, au, no Total: 120 min DR: 41 min TR: 25 min
31	09.03.2006 End of Cabri-use interview: Frode, Jakob Harald, Ingvald	An end of Cabri-teaching interview considering teaching with Cabri at Austpark. The teachers talked about their planning, how they experienced their teaching and students' achievements, consequences for coming teaching.	au, no Total: 34 min DR: 34 min TR: 31 min

32	10.03.2006 Classroom visit, Cabri: Trude	In the lesson Trude's students worked with tasks in Cabri presented on the flip-chart: Symmetry tasks. Drawing. Trude had a supportive pedagogical style, very engaged commenting with words such as: "You are clever", "Excellent!"	vi, no Total: 90 min
33	10.03.2006 Conversations after lessons, Cabri: Trude	Two brief conversations after Trude's teaching with Cabri (see Event 32). In the conversations Trude emphasised advantage and disadvantage of giving tasks without telling how to do it. She planned to include more description for the weakest students in her next lesson with Cabri. Trude emphasised that the students were more progressive and wanted to investigate things which she mentioned as being fun particularly by referring to one of her student's, Liv. Trude argued that her way to set up the session triggered her best students most.	au, no Total: 17 min DR: 6 min TR: 2 min
34	23.03.2006 Focus Group Interview LCM/ ICTML, Fjellet: Markus, Sylvi (Grade 1), Eli, Tor	Focus Group interview after phase 2 in LCM and ICTML. Trude had a break from teaching for the rest of the school year and did not participate in the interview. Among other things, issues related to school development was brought up	au, no Total: 61 min DR: 61 min TR: 61 min
35	29.03.2006 Focus Group Interview LCM/ ICTML, Austpark: Frode, Jakob Elise, Gunnar, Harald, Vice principal, Aud, Eli, Ingvald	Focus Group interview after phase 2 in LCM and ICTML. In the interview Harald emphaised Jakob's importantce in the process of development of ICT use at Austpark. Jakob commented on use of Cabri and spreadsheet and a Cabri course at school by Otto as important outcome of the projects. Development in students' learning was considered but argued as a very slow process by Harald, but Frode reported about improved learning after use of Cabri and spreadsheets.	au, no Total: 63 min DR: 63 min TR: 63 min
36	30.05.2006?? Computer lab visit, Cabri and Excel: Jakob	Carry out of Cabri and Excel tasks as part of the year examination at Grade 8	au, no Total: 45 min
37	30.05.2006 Computer lab visit, Cabri and Excel: Jakob	Jakob with a review of Cabri and Excel tasks included in their designed year examination inj mathematics. During the review session, his students were supposed to start to correct their solutions. Jakob gave something he called an open task for the students who finished the correction of their test-file: The open task was about Pythagoras and areas.	vi, no Total: 90 min

38	05.09.2006 KUL confer- ence presenta- tion: Frode, Jakob, Harald	Jakob and Frode reported from their implementation and use of Cabri at Grade 8 at Austpark. Design of tests, use of the written teaching package by Bueie and little inquiry were elements emphasised in their presentation.	vi, no Total: 41 min DR: 41 min TR: 21 min
39	29.11.2006 ICTML-WS10: Jakob, Aud, Ingvald, Otto	A brief passage where Jakob focused on constraints in software and rationale for changing from Cabri to GeoGebra in teaching at Grade 8 at Austpark.	vi, no Total: 71 min DR: 71 min TR: 2 min
40	15.01.2007 Computer lab visit, GeoGebra: Jakob	From a lesson with use of GeoGebra but students used the same teaching package as one year earlier designed for Cabri. Theme: Construction of 60 and 90 angles. Jakob about his and Elise's experience of GeoGebra and plans to give students tasks with GeoGebra at home.	au, no Total: 35 min
41	21.01.2007 KUL book chapter from Austpark: Jakob, Frode	The teachers at Austpark's book chapter in a book with contributions from participants at the KUL conference.	Copy
42	June 2007 E-mail re- sponses: Aust- park (Jakob, Frode, Harald, Gunnar and Elise)	Responses to an e-mail sent by Ingvald in June 2007 to the 5 teachers in the projects at Austpark. The teachers responded to three questions concerning their educational background, experience from teaching and experience from use of computer software in mathematics teaching. All the five teachers responded.	Copy
43	17.01.2008 E-mail re- sponses: Trude	Trude's response to an e-mail request concerning further use of Cabri after her initial use in January-March 2006. The e-mail also asked for the same information as the e-mail request to the teachers at Austpark (see Event 42)	Copy
44	22.01.2008 End of ICTML project inter- view with Aud	Reflection interview based on experiences after the support offered at Vestpark, Fjellet and particularly Austpark in autumn 2005 (see Event 3, 4, 5, 6 and 8)	au Total: 38 min DR: 38 min min TR: 13 min

<u>Sum in minutes of data collected related to the case:</u>

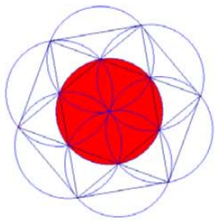
Total occurrence of events:	2624	minutes
Number of minutes data reduced (DR):	1090	minutes
Number of minutes transcribed (TR):	347	minutes

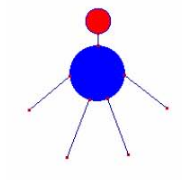
Appendix 2 Worksheets in Bueie's teaching package

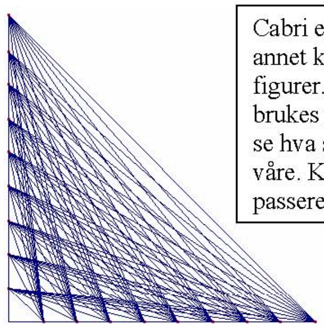
Appendix 2a) Copy of Worksheet 1

Cabri kursark 1 – vi leker oss

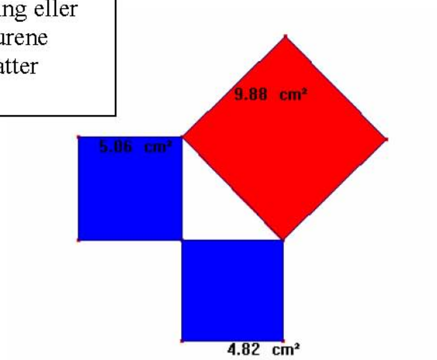
© Henning Bueie

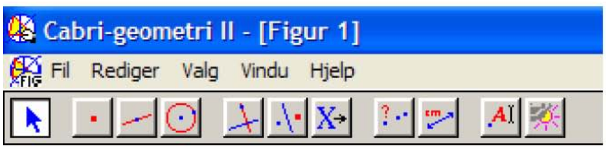






Cabri er et konstruksjonsprogram som vi blant annet kan bruke til å tegne og konstruere flotte figurer. Cabri er også et verktøy som kan brukes når vi skal drive problemløsning eller se hva som skjer når vi endrer på figurene våre. Konstruksjonsprogrammet erstatter passerens oppgaver og mer til.





Verktøylinjen i Cabri ser slik ut. Ved å holde inne venstre musknapp på linjen eller sirkelen får du opp en undermeny som vist under.

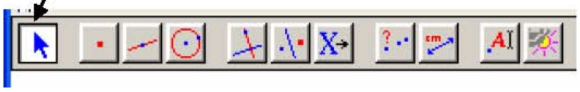
Oppgave 1

a) utforsk de ulike funksjonene på menyen. Tegn en **linje**, et **linjestykke**, en **sirkel** og et **punkt** på skjermen.

b) Forklar til sidemannen hva som er forskjellen på **linje** og **linjestykke**

c) Tegn en trekant på skjermen ved hjelp av **linjestykker**.

d) Trykk på pila på verktøylinjen, ta så tak i et hjørne av trekanten og hold inne venstre musknapp, mens du forsøker å endre på trekanten.



Oppgave 2

a) hent fram et nytt arbeidsark (gå på Fil og Ny).

b) Bruk **sirkler** og **linjestykke** til å tegne et menneske. Sirklene skal være magen og hodet, og linjestykkene skal være armer, bein og nakke på figuren (**se figuren øverst på arket**).

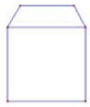
c) Fargelegg hodet og magen på figuren din ved hjelp av funksjonen **fyll ut**

d) Lagre figuren i mappen din med navnet ”Kursark 1 – oppgave 2”

Oppgave 3

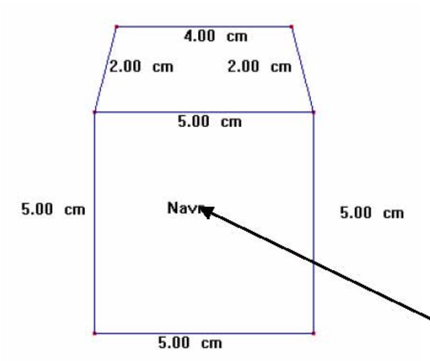
a) hent fram et nytt arbeidsark

b) bruk **linjestykker** og tegn en enkel postkasse som vist her



c) Bruk funksjonen **avstand og lengde** til og måle alle sidene på postkassen

d) Bruk samme metode som i oppgave 1d og endre på postkassen slik at postkassen får samme målene som på postkassen under.



e) Bruk funksjon **skriv kommentar** og merk postkassen med navnet ditt

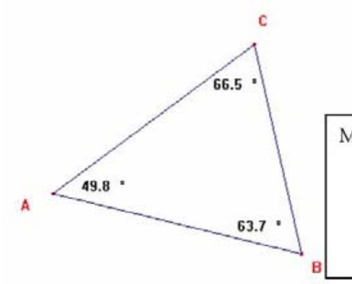
f) Lagre figuren i mappen din med navnet ”Kursark 1 – oppgave 3”

Oppgave 4

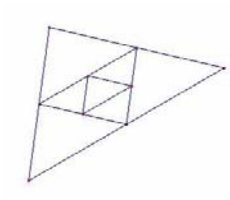
Tegn et ansikt **eller** en bil ved hjelp av linjestykker og sirkler. Forsøk og få med flest mulig detaljer.

Appendix 2b) Copy of Worksheet 2

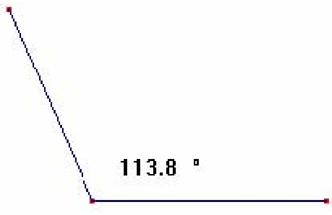
Cabri kursark 2 – vinkler © Henning Bueie



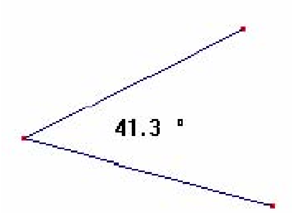
Mål for leksjonen:
- lære å måle vinkler
- lære å sette navn på punkt
- lære hva en spiss vinkel, en stump vinkel og en rett vinkel er.
- oppdage vinkelsummen i en trekant



Stump vinkel

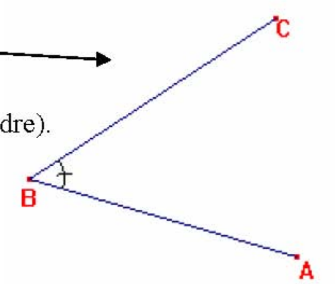


Spiss



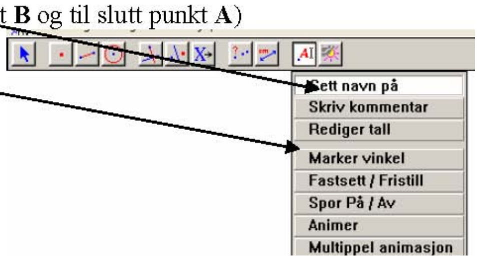
Oppgave 1

Symbolet for en vinkel er ∠. Dette tegnet må ikke forveksles med < som betyr "mindre enn". Vinkelen ABC kan skrives slik: ∠ABC, eller noen ganger bare som ∠B. Vinkelen kan se slik ut:



En vinkel består av to vinkelbein og et toppunkt.
Toppunktet er der hvor vinkelbeina møtes (eller krysser hverandre).
AB og BC er **vinkelbein** og B er **toppunktet**. I denne figuren kunne vi kalt vinkelen for ∠B, men vi skal senere se at vi av og til må kalle vinklene med vinkelbein, altså ∠ABC, for å unngå missforståelser.

a) Bruk linjestykker og tegn opp en figur som vist over
b) Bruk funksjonen **sett navn på** til av navngi de tre punktene
c) Bruk funksjonen marker vinkel for å sette på buen som markerer vinkelen (trykk først **marker vinkel**, deretter punkt **C**, så punkt **B** og til slutt punkt **A**)



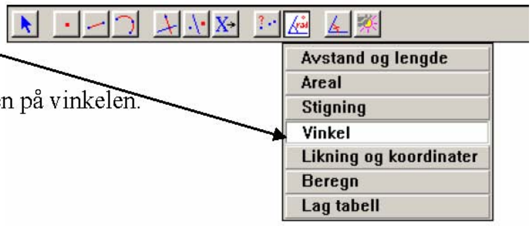
Oppgave 2

Lengde måles i meter og tid i sekunder eller timer. **Vinkler** måles i **grader**. Dette har ingen ting med temperatur å gjøre, men symbolet vi bruker er det samme. 30 grader skrives 30º. En sirkel måler 360°. Cabri kan vi også bruke til å måle vinkler.

a) Gå på Fil-Ny.Tegn opp en figur som i oppgave 1. Sett navn på de tre punktene som i oppgave 1b.

b) Bruk funksjonen **vinkel** og mål størrelsen på vinkel B. (Trykk vinkel, deretter punkt C, så B og så A)

c) Ta tak i punkt C eller A, hold inne venstre musknapp og forsøk og endre på vinkelen. Se hvordan gradtallet endrer seg med størrelsen på vinkelen.



Oppgave 3

En rett vinkel, er en vinkel som er 90°. Kalles også for 90 graders vinkel.

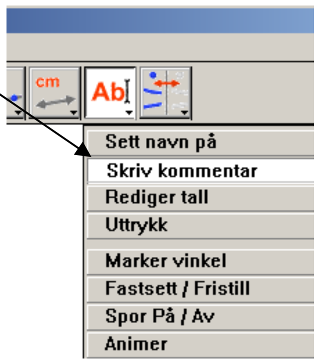
En spiss vinkel, er en vinkel som er mindre enn 90º.

En stomp vinkel, er en vinkel som er større enn 90º.

a) Bruk linestykker og tegn opp 6 vinkler som i oppgave 1 (husk å sette på navn på vinklene og å markere buen på vinklene)
b) Mål størrelsen på de 6 vinklene på samme måte som i oppgave 2b.
c) Juster de 6 vinklene slik at en av dem blir en **rett vinkel**, to blir en **spiss vinkel** og tre blir en **stump vinkel**
d) Bruk funksjonen **skriv kommentar** og skriv under hver vinkel om den er **spiss**, **stump** eller **rett**
e) Lagre figuren i mappen din med navnet "Kursark 2 – oppgave 3".

Oppgave 4

a) Gå på Fil-Ny. Tegn opp en stor trekant ved hjelp av linjestykker.
b) Kall de tre hjørnene A, B og C ved hjelp av funksjonen sett navn på.
c) Marker og mål de tre vinklene i trekanten. Hva blir summen av vinklene?
d) Prøv å endre på trekanten ved å trekke i et av hjørnene. Hva blir summen nå?
e) Prøv igjen å endre på trekanten. Hva blir summen nå?
f) Ser du noen sammenheng. Skriv ned sammenhengen ved hjelp av **skriv kommentar** og lagre filen som "Kursark 2 – oppgave 4".



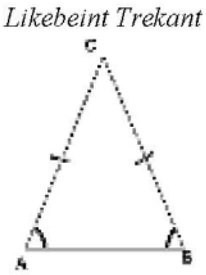
Appendix 2c) Copy of Worksheet 3

Cabri kursark 3 – navn på trekanter, konstruksjon av 60º og 90º vinkel

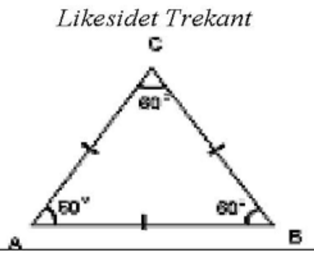
© Henning Bueie

Mål for leksjon: - lære hva en likebeint og en likesidet trekant er - se på sammenhengen mellom størrelsen på vinklene og lengden på sidene i en trekant - konstruksjon av 60º og 90º vinkel

Oppgave 1

	Dersom to av sidene i en trekant er like lange er trekanten **likebeint**. "Pinnene" på sidene AC og BC markere at disse sidene er like lange. Når to sider i en trekant er like lange medfører det at to vinkler er like store. I dette eksempelet er vinkel A og vinkel B like store.

a) Tegn opp to trekanter ved hjelp av **linjestykker.** Sett navn på hjørnene.
b) Mål lengden på sidene i den ene trekanten og mål vinklene i den andre.
c) Juster de to trekantene slik at de begge blir likebeinte.
d) Skriv en kommentar(**Skriv kommentar**) om hvorfor de to trekantene nå er likebeinte.

	I en likesidet trekant er alle sidene like lange og alle vinklene er 60°

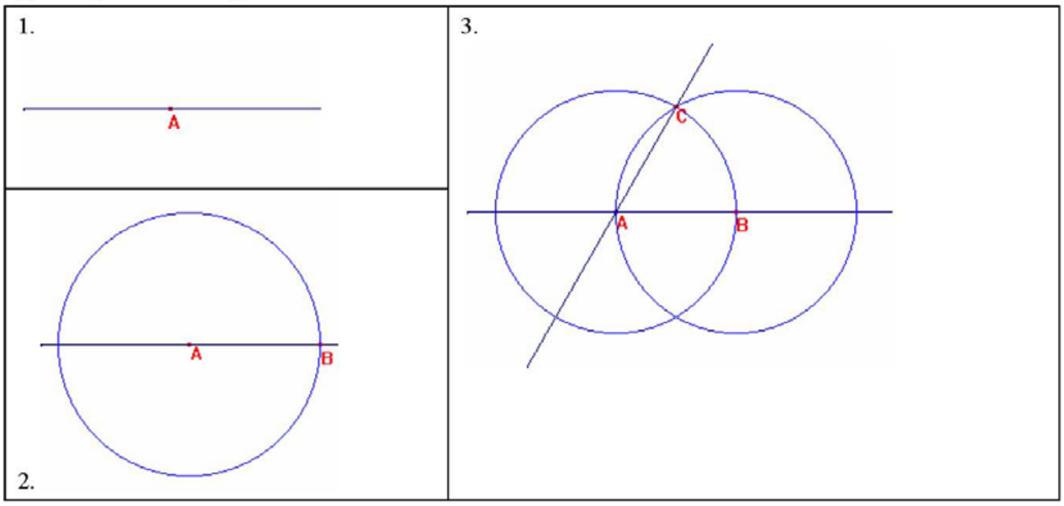
e) Juster de to trekantene slik at de begge blir likesidet.
f) Skriv en kommentar(**Skriv kommentar**) om hvorfor de to trekantene nå er likesidet.

Oppgave 2

a) **Konstruer** en 60° vinkel.

Konstruksjon av 60° vinkel.

1. Tegn en **linje** og avsett et **punkt** A, der du ønsker toppunktet.
2. Tegn en **sirkel** med sentrum i A. Kall skjæringspunktet mellom sirkelen og linjen for B.
3. Tegn en ny **sirkel** med sentrum i B som går gjennom A. Kall skjæringspunktet mellom sirklene for C. Trekk opp en linje mellom A og C.



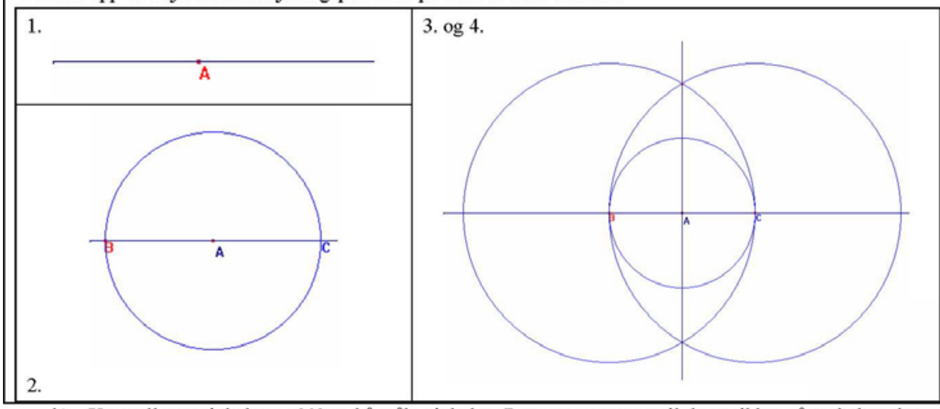
b) Kontroller at vinkelen er 60° ved å måle vinkelen. Repeter oppgave a til du er sikker på at du kan det.

Oppgave 3 Konstruer en 90° vinkel

a) **Konstruer** en 90° vinkel

Konstruksjon av 90°.

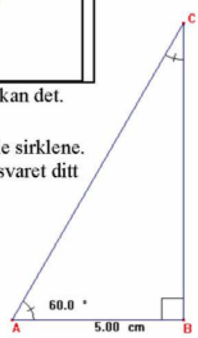
1. Tegn en **linje** og avsett et **punkt** A, der du ønsker toppunktet.
2. Tegn en **sirkel** med sentrum i A.
3. Tegn en **sirkel** med sentrum i B der sirkellinjen festes til C. Tegn så en ny sirkel med sentrum i C det sirkellinjen festes til B.
4. Trekk opp en linje mellom skjæringspunktene på disse to store sirklene.



b) Kontroller at vinkelen er 90° ved å måle vinkelen. Repeter oppgave a til du er sikker på at du kan det.

Oppgave 4

Konstruer en trekant ABC med AB = 5 cm. ∠A 60° og ∠B 90° . Bruk funksjonen **skjul/vis** til å skjule sirklene. Hvordan kan du vite hvor stor ∠C blir uten å måle? **Skriv kommentar** og begrunn svaret. Kontroller svaret ditt ved å måle vinkelen. Lagre konstruksjonen som ”Kursark 3 – oppgave 4”.

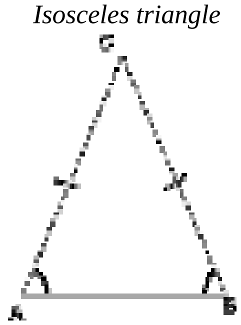


Appendix 2d) Worksheet 3 translated to English[36]

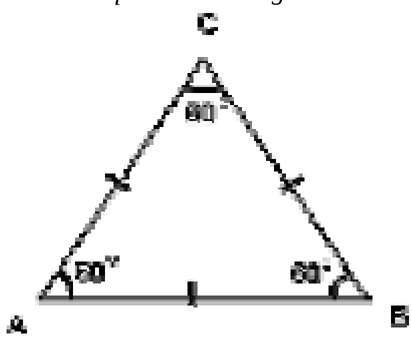
Cabri Course Worksheet 3 – names of triangles, Construction of 60º and 90º angles

Goals for the lections - learn what isosceles and equilateral triangles are - study the relationship between the angles and the length of the laterals in a triangles - construction of 60º and 90º angles

Task 1

Isosceles triangle 	If two of the laterals in a triangle have the same length, the triangle is **isosceles.** The “markers” on the laterals AC and BC marks that these laterals have the same length. When two laterals in a triangle have the same length it implies that two angles are equal. In this example angle A and angle B are equal.

a) Draw two triangles by applying **segment.** Label the corners.
b) Measure the length of the laterals in one of the triangles and measure the angles in the other one.
c) Adjust the two triangles so both become isosceles.
d) Write a comment (**Text**) about why the two triangles now are isosceles.

Equilateral triangle 	In an equilateral triangle all the laterals have equal length and all the angles are 60°

e) Adjust the two triangles so both become equilateral.
f) Write a comment (**Text**) about why the two triangles now are equilateral.

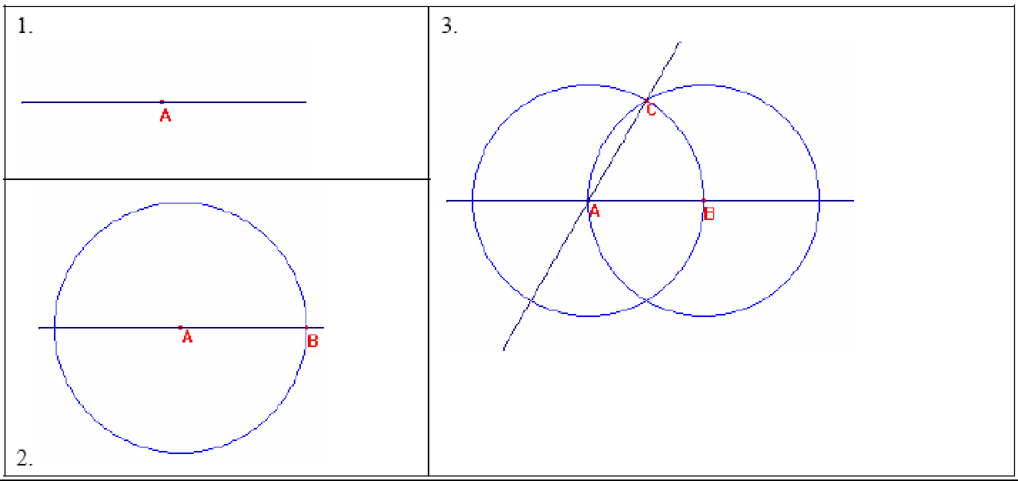
[36] The translation of Worksheet 3 to English has been made by the author of the thesis

Task 2

a) **Construct** a 60° angle.

Construction of 60° angle

1. Draw a **line** and create a **point** A where you want the vertex.
2. Draw a **circle** with centre in A. Name the intersection point B between the circle and the line.
3. Draw a new **circle** with its centre in B which passes through A. Name the intersection point C between the circles. Draw a line between A and C.



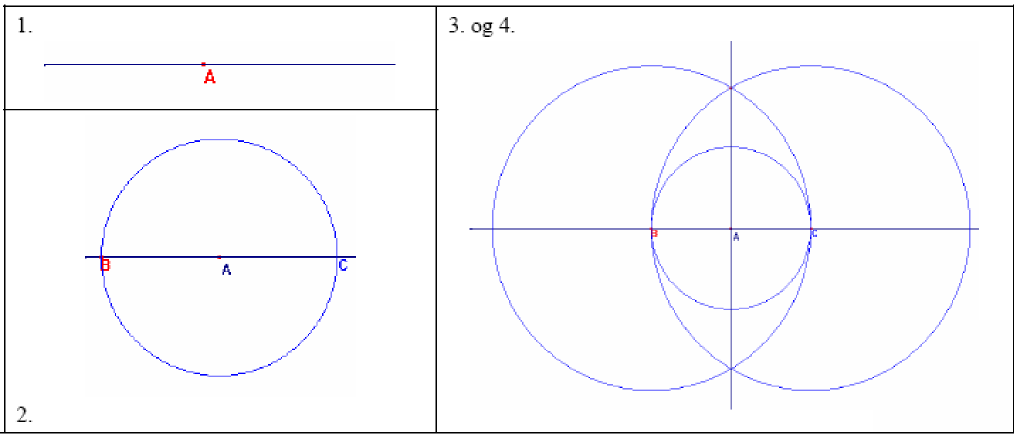
b) Verify that the angle is 60° by measuring. Repeat exercise a until you are sure you mange it.

Task 3

a) **Constructions** of 90° angles

Construction of **90°.**

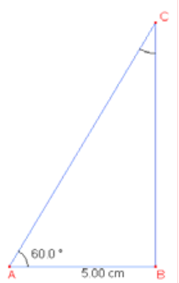
1. Draw a **line** and a **point** A on the line where you prefer to have the vertex.
2. Draw a **circle** with centre in A.
3. Draw a **circle** with centre in B and attach the circumference of the circle to C. The draw a new circle with centre in C and attach the circumference to B.
4. Draw a line between the points of intersection on the two big circles



b) Verify that the angle is 90° by measuring. Repeat exercise a until you are sure you mange it.

Task 4

Construct a triangle ABC with AB = 5 cm. $\angle A$ 60° og $\angle B$ 90° . Apply the function **hide/show** to hide the circles. How can you know the size of C without measuring it? Use **Text** and substantiate your answer. Control your answer by measuring the angle. Save the construction as "Course worksheet 3 – Task 4".



Appendix 3 Statement in geometry topic at Grade 8

Pupils should have the opportunity to

- gain experience in creating and examining patterns, for instance covering surfaces with polygons
- examine, make, draw and construct figures using various tools and classify the figures according to their properties
- experience three-dimensional figures and try to discover rules for perspective drawing
- work on parallelism and the measurement of angles, draw and construct angles, perpendicular norms and parallels, and apply this where relevant
- continue working on scales in connection with maps, and when making and using simple working drawings
- continue working on measures, on choosing appropriate measuring tools and units of length, on finding and calculating areas and volumes of simple and complex figures, and on making estimates and evaluations

From the official English version of the Norwegian National Curriculum L97 (Hagness & Veiteberg, 1999, p. 179-180; KUF, 1997, p. 167)

Appendix 4 Questions to LCM/ICTML focus group interview

Appendix 4a) Focus group questions in Norwegian

1) Hvorfor ønsket dere å være med i prosjektene?
2) Hva ser du på som verdifullt i å være med?
3) Hva har vært vanskelig eller problematisk?
4) Hvordan vil du beskrive arbeidet til skoleteamet?
5) Hva slags arbeid i undervisningen har vært relatert til prosjektene?
6) På hvilke måter har workshopene bidratt (verdifullt)?
7) Er det noe du savner som du skulle ønske var på workshopene?
8) I denne fasen (av prosjektene), hva ønsker dere å gjøre i relasjon til prosjektene?
9) Hva ønsker dere å gjøre i forbindelse med målene for skolen, om disse er relevant for prosjektene eller ikke?
10) Hvordan ser du på begrepene/ordene "inquiry" og "community" som relevant for ditt arbeid og utvikling her på skolen?
11) Hvordan ser du/dere på de forskjellige rollene som didaktikere og lærere har i prosjektet?
12) Har du brukt tilbakemeldingene fra longitudinelle testene på deres skole?

Appendix 4b) Focus group questions translated to English

1) Why did you want to join this project?
2) What have you found valuable?
3) What has been difficult or problematic?
4) How would you describe the work of the school "team"?
5) What kind of work in classrooms has been related to the project?
6) In what ways have workshops contributed valuably?
7) What would you have liked from workshops that was not available?
8) At this stage, what would you like to do in relation to the project?
9) What do you want to do in connection with your school goals, whether or not this relates to the project?
10) How do you see the concepts of inquiry and community being relevant to your work and development in school?
11) How do you see the different roles that didacticians and teachers have in the project?
12) How have you used the feedback from the longitudinal tests in your school?

Appendix 5 Copy of materials from teachers

Appendix 5a) Reporting scheme in the ICTML project

Exemplified with Trude's reporting scheme for the period November 2005-March 2006, delivered in March 2006 (Translated to English)

Logg ICTML Class/grade: 8 Skole: Fjellet School Teacher: Trude

Date /week	Task, brief description problem	Excel	Cabri	Graf-box	Other software	Accomplishment, experiences
18.11. 2005	Statistics	X				UiA / Otto
25.11. 2005	/ diagrams	X				UiA / Otto
06.01. 2006	Introduce. Point, line, circle, equilateral triangles		X			Half of the class at a time
20.01. 2006	Repetition equilateral triangles. Symmetry, labels A, B, C. Isosceles and right-angled triangle. Perpendicular		X			Half of the class at a time. The other half of the class have a review of a test and work with fractions. Vist from UiA.
17.02. 2006	Polygons, stars		X			2 x ½ class (one hour). Fun, easy,
24.02. 2006	Distance, lengths, area (snowmaen). Triangle, similar circumference/ area. Other polygons		X			UiA visit from Aud 2 hours with ½ class (the first went fine, the second difficult with consentration)
10.03. 2006	Snowman		X			Visit from UiA
17.03. 2006	Cabri Worksheet Bueie		X			Good, because they had good previous knowledge. Fun.

Appendix 5b) Copy of Cabri-survey at Austpark

SPØRREUNDERSØKELSE

Dette er en undersøkelse om hvordan du opplevde opplegget i geometri.

Svar så ærlig du kan på spørsmålene.

Kryss av: ☐ Jente ☐ Gutt

1. Fra barneskolen

a) Har du brukt gradskive i matematikktimene før?

☐ Nei, aldri ☐ Ja, 1-2 ganger ☐ Ja, 3-6 ganger ☐ Ja, mange ganger

b) Har du konstruert med passer på barneskolen?

☐ Nei, aldri ☐ Ja, 1-2 ganger ☐ Ja, 3-6 ganger ☐ Ja, mange ganger

c) Hva lærte du om konstruksjon (bruk av passer)? Kryss gjerne av flere.

☐ Ingenting

☐ Konstruere 90° ☐ Konstruere 60° ☐ Å halvere ☐ Konstruere trekanter

2. Om Cabri

a) Hvordan var det å bruke programmet (å finne fram til riktige knapper og sånn)?

☐ Lett ☐ Ganske lett ☐ Ganske vanskelig ☐ Vanskelig

b) Hvordan var det å konstruere normaler, vinkler og trekanter i Cabri?

☐ Lett ☐ Ganske lett ☐ Ganske vanskelig ☐ Vanskelig

3. Om undervisningen i klasserommet

Hvordan var det å forstå konstruksjon av normaler, vinkler og trekanter da du brukte passer og linjal?

☐ Lett ☐ Ganske lett ☐ Ganske vanskelig ☐ Vanskelig

4. Om kombinasjonen av Cabri og vanlig undervisning.

a) Synes du det var lettere å forstå konstruksjon av normaler, vinkler og trekanter da du brukte <u>både</u> Cabri <u>og</u> passer/linjal?

☐ Nei, jeg skulle ønske vi bare hadde brukt Cabri.

☐ Nei, jeg skulle ønske vi bare hadde brukt passer og linjal.

☐ Ja, jeg forsto geometri bedre da vi brukte både Cabri og passer/linjal.

b) Hva mener du at du mestrer <u>nå</u>? (kryss gjerne av flere)

I Cabri

☐ Å konstruere 90°

☐ Å konstruere 60°

☐ Å halvere

☐ Å konstruere en trekant

Med passer og linjal

☐ Å konstruere 90°

☐ Å konstruere 60°

☐ Å halvere

☐ Å konstruere en trekant

5. Om bruk av pc og læring

Når synes du at du lærer best på datalabben?

☐ Når lærer viser eksempler på sin pc/prosjektør først og jeg gjør det samme på min pc etterpå.

☐ Når jeg får et opplegg med oppgaver og kan jobbe selvstendig og spør lærer og medelever når jeg trenger hjelp.

☐ En kombinasjon av de to første punktene.

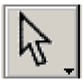
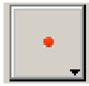
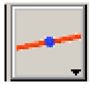
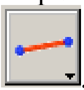
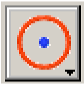
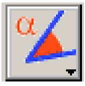
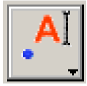
☐ Annet:

6. Gi oss noen tips til hva du synes vi kunne gjøre annerledes for at det skal bli lettere å forstå geometri. *Bruk baksiden av arket*

Appendix 5c) Copy of Cabri-test at Austpark

Prøve geometri – Cabri

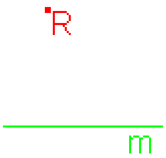
- Opprett ei fil i Cabri som du lagrer som: ”PrøveNavnKlasse” (Eks. ”PrøveTerje8C”) Du skal gjøre ***alle*** oppgavene på samme arket (samme fil).

På prøven har du lov til å bruke: peker , punkt , linje , linjestykke , sirkel , vinkel , sett navn på . Ikke bruk noen av de andre.

1.
   a. Tegn ei linje og avsett et punkt på linja. Sett navn på linja. Kall den for ”k”. Sett navn på punktet. Kall det for ”P”.

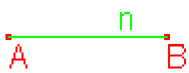
   b. Opprett en normal på ”k” i punktet ”P”. (linje som står 90 grader på linja ”k”)

2.
   a. Tegn ei linje og avsett et punkt over linja. Sett navn på linja. Kall den for ”m”. Sett navn på punktet. Kall det for ”R”.



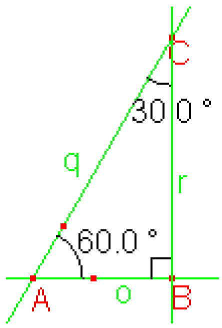
   b. Konstruer en normal fra ”m” og ned på ”R”

3.
   a. Tegn et linjestykke. Kall endepunktene for ”A” og ”B”. Kall selve linjestykket for ”n”



   b. Konstruer en midtnormal på linjestykket.

4.
   a. Tegn ei linje ”o” og marker et punkt ”A” på linja.
   b. Konstruer en vinkel på 60 grader i ”A” og kall den nye linja for ”q”
   c. Avsett et punkt ”C” på ”q” (du velger selv hvor).
   d. Konstruer en vinkel på 30 grader i ”C” slik at den nye linja ”r” skjærer ”o” i punkt ”B”. Har du konstruert riktig, så er vinkel ABC 90 grader.



5. Lagre fila som ”PrøveDittnavnKlasse” og send den til tidland@skolepost.no via skole-nettet.

Appendix 6 Processing of data

Appendix 6a) Map of data

Exemplified with the map of data related to Jakob

Date of and type of event	Description	Main elements	Material
051026: STM-ICTML	Meeting requested by didacticians	Issues, aims	au, no, e-mail
051104: STM-LCM	Follow-up, requested in a letter	Issues, aims	au, no, letter
051207: STM- Cabri	Planning implementation of Cabri	Issues, aims, use of tp	au, no
051212: STM-Cabri course	Working session with Cabri led by Otto	Teachers' Cabri competence	au, no
060110: CV-Cabri and compas-	Lessons with compasses and Cabri	Orchestration of students' work	Tp, au, no
060111: LCM ws session	Reportimng from Cabri-teaching	About teaching Cabri, issues	au, no
060117: CV-Cabri	Cabri lesson, use of a teaching package	Aims for orchestration	Tp, au, no, vi
060118: ICTML ws session	Reporting from Cabri-teaching	About Cabri use, tool skills	vi, no
060207: CV-Cabri	Review of Cabri-test	Orchestration, tool skills	au, vi, no Ct,
060221: CV-Excel	Work with Excel, use of a teaching package	Orchestration	vi, no, tp
060222: LCM ws session	About teaching Cabri	Students' tool skills, inquiry	au, no
060307: CV-Geometry	Calculating school building area		vi, no
060309: End of Cabri-use inter-	Discussing implementation and use of Cabri	Issues, outcome, inquiry	au, no
060329: FGI- LCM/ICTML	Discsuiing participation in the projects	Achievements, roles, plans	au, no
060530: CV-Year examination	Examination at the end of Grade 8 with ICT	Students' techniques	au, no, Ct, sf
060606: CV-Review exam	Review of the ICT part of the examination	Tool skills, techniques	au, vi, no
060906: CP-Presentation	School report from implementation of Cabru	Issues, outcome, inquiry	vi, no

Labels:

STM = School Team Meeting
CV = Classroom or computer lab visit
CP = Conference presentation
FGI = Focus group interview

au = audio
vi = vido
no = neotes

tp = teaching pacakge
Ct = Cabri test
sf = students' solution file

Appendix 6b) Codes and categorisation of codes

Some of the codes developed when studying transcripts.

1. Time
2. Lack of access
3. Motivation
4. Frequent use
5. Good tasks
6. Colleagues resistance
7. Utilising tools in parallel
8. Teachers' tool skills
9. Students' roles
10. Students' learning outcome
11. Teaching package
12. Students' tool skills
13. Fun teaching with computer software
14. Problem solving
15. Inquiry
16. Teachers' intervening in students' work

A categorisation of codes:

a) Aims for and issues in the implementation process (1, 2, 3, 4, 5, 6, 8)
b) Orchestration of Cabri-use and students' achievements (7, 9, 10, 11, 12, 13, 14, 15, 16)

Appendix 6c) Data reduction from LCM Workshop 10

Event:	LCM-Workshop 10 at UiA
Date:	11.01.2006 (060111)
Presence:	Group 1 session: Ingvald, Otto, Harald, Frode, Jakob, Trude
Handling type:	Data reduction made on 060112 by IE
Time:	12.30 – 12.46
Data type:	Audio recording
Background information:	The first part of a group session concerning what teachers have emphasised in their lesson, related to geometry and activities in LCM W9. However, this part of the session emphasised mainly use of Cabri in geometry lessons.

Time on audio	What happened (in Norweigian)	Short (in English)
00.00 – 01.30	Ingvald kort om ideen med gruppeøkta. Høre litt om hva som har skjedd siden forrige LCM workshop evt gjort noe spesielt i klasserommet og hvordan vi evt kan endre opplegget i workshop' en for bedre å støtte aktivitet i klasserommet..	Ingvald: Brief introduction to the group session
01.30 - 05.00	Trude: Ikke noe relatert til LCM-W9. Har hatt tentamen + kjørt IKT, viser til Otto og Ingvalds besøk. Har satt i gang med Cabri forrige fredag. Planlegger å kjøre hver fredag fram til påske. Deler klassen Lage punkt, linje, sirkel, konstruere likesidet trekant. Lage midtnormal vha sirkler. Erfaring: Moro, satt med hver sin maskin → Noen fikk det til → spredte seg. Refleksjon Trude :Ga kjempefin læring, vi lærer sammen, kaster meg ut i det. Harald (05.00): Stilig at du setter i gang å bruke det før du føler du behersker det. Ellers blir det aldri. Otto: Jeg lærer fortsatt noe av elevene mine	Trude about her: - first ever lesson with Cabri. - further plans for use of Cabri - interpretation of students collaborative learning
05.40 – 12.18	Frode: (05.40) Alle våre klasser skal jobbe på datalabben med Cabri. Lære sammen/prøve seg fram med elevene. Bruker materiell fra Henning Bueie. - Elevene synes det er veldig gøy. - Kombinerer klassiske matematikktimer og datarommet - På datarommet brukes Bueies materiell, intro vha prosjektør men ellers selvinstruerende. Jakob: (08.15) Viser til kurs av Otto på Austpark før jul, viktig for å få i gang alle/flest mulig av lærerne på Austpark.	Frode about: -the five teachers at Austpark planning to use Cabri. - about Grade 8: use of a teaching package and use of both Cabri and compasses. - Comments concerning students' motivation.

	Harald: Det som er spennende er å få med de som ikke er med i mattegruppa. De fleste med (alle i 8. klasse, en ikke med i 9.ende) Frode: Utfordring å lage vår-tentamen der elevene blir tes-tet i dette. Alle i 8. trinn bruker dette så det kan gå an. Otto Kan jo håpe at de blir bedre til å bruke passer og linjal når de har brukt Cabri. Viser også til egne prøver i prosjektet han hadde som de kan få.. Eleve-ne fikk en figur de skulle gjenskape – levere inn fil med forklaring og utskrift	- Design of tests - Otto's contribu-tions at Austpark
12.18 – 16.05	Jakob: Om timene dagen før – vinkel, grader, vinkelsum. Ingvald kommenterer fra besøket (Dette er Event 13 og 14 i caset). Jakob kommentarer at arbeidsarkene er lite utforskende, satser på mer utforskning etter hvert. Trude om egen og elevens utforsking av verk-tøyene	Jakob about: - His Cabri lesson the previous day. - Interpretation of teaching package minimally investiga-tive. - Trude adds

Appendix 6d) Transcriptions from LCM Workshop 10

Below I have presented transcription from 06.50-07.30 in the workshop session briefly described in the data reduction in Appendix 6c). Two episodes from this segment of the transcription are included in the thesis. These are Episode 13 with utterances 384-386 (see p. 234), and Episode 14 with utterances 398-402 placed in Appendix 8ix (see p. 347).

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384. Jakob Så de de kursarkene de er de er ikke sånn veldig sånn veldig utforskende av natur de er veldig sånn eh egentlig fokusert på å få prøvd verktøyet litte grann
[og få]
385. Trude [Ja.]
386. Jakob Så jeg tror nok etter hvert når de har kommet seg igjennom og lært verktøyet litt så kan man nok begynne å ta det i bruk litt mer utforskende virksomhet da.
387. Trude For mitt problem var at at jeg kunne jo ikke alle verktøyene selv jeg.
388. NN: Nei.
389. Jakob Nei
[(…)]
390. Trude [Og og og]
391. NN: [(…) huske på.]
392. Trude men jeg tenkte sånn at dere har verktøyet der dere må se og og dermed så prøvde de seg fram og
[så]
393. NN: [Mm.]
394. Trude sa jeg ga jeg noen bruk de fire først.
395. IE Mm.
396. Trude Og så se på det først.
397. NN: Mm.
398. Jakob Eh han har også lagt pensumet for jeg kikket igjennom boka og han har lagt pensumet for geometri i åttende klasse inn i de kursarkene som han har da.
399. Trude [Å ja]
400. NN: [Mm.]
401. Trude det var kjempesmart.
402. Jakob Eneste han mangler er symmetrien der der vil jeg bruke noe som som Otto har på sine ark, han hadde noe.

Appendix 6e) Official LCM and ICTML transcriptions keys

TRANSCIPTION KEYS IN KUL-PROJECT

Audio and video transcripts

,	Comma
.	Full stop
?	Question mark
!	Exclamation mark
(3s)	Pause of greater than 2 seconds
(*Italic*)	Describing non-verbal sounds or gestures/actions. *Like laughter, coughing, paper-noise etc. or other comments from the transcriber.*
Italic	Mathematical expressions
Bold	Emphatic speech
(…)	Words undeciphered. Used when the transcriber is in doubt of what is said or how words are spelled. I.e. names, titles etc.
[ ]	Simultaneous or interrupted speech Example: Eli: Yes this was interesting. Tor [do you have any comment] Aud: [Do you really think this was] Eli: to us about this?
[Italic] Example:	Small interruption within a turn BJ: So, so what we're saying here, and I think we are agreeing [mm] that, eh, what is happening at the workshop is that what they've written so far [mm] is helping them to recall what they have been thinking about, and the video will also help with that.
. . .	Omitted discourse which is irrelevant to the issue being discusses (mostly used when there is a break in the meeting and before the meeting has started)

Appendix 7 List of data excerpts used in the analysis

Notice: Episodes are presented in Chapters 5-7 except for those with reference to Appendix 8 who are attached as endnotes.

Event 1, Jan 26th 2005, UiA, ICTML Workshop 3, Video

- Episode 1 (utterances 116-123)
- Episode 2 (utterances 189-192)
- Episode 3 (utterances 219-226)
- Episode 4 (utterance 253)
- Episode 5 (utterances 266-271)

Event 2, Apr 20th 2005, UiA, ICTML Workshop 4, Video

- Episode 1 (utterances 19-25)
- Episode 2 (utterances 26-32)

Event 3, Sep 28th 2005, Aud, E-mail concerning ICTML

- Episode 1

Event 4, Oct 14th 2005, Aud/Eli, Letter to Austpark

- Episode 1

Event 6, Oct 26th 2005, Austpark, School team meeting, Audio

- Episode 1 (utterances 316-330)
- Episode 2 (utterances 331-339)
- Episode 3 (utterances 353-363)
- Episode 4 (utterance 373)
- Episode 5 (utterances 397-402)

Event 7, Oct 27th 2005, UiA, KUL team meeting, Audio

- Episode 1 (utterance 43)

Event 8, Oct 27th 2005, Harald, E-mail concerning ICTML

- Episode 1

Event 10, Dec 1st 2005, UiA, KUL team meeting, Audio

- Episode 1 (utterance 95)
- Episode 2 (utterance 120)

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio

- Episode 1 (utterances 12-18) in Appendix 8vi
- Episode 2 (utterances 29-36)
- Episode 3 (utterances 37-40)
- Episode 4 (utterances 48-56)
- Episode 5 (utterances 71-76)
- Episode 6 (utterances 82-85)
- Episode 7 (utterances 114-117)
- Episode 8 (utterances 132-140)
- Episode 9 (utterances 141-156) in Appendix 8v

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio

- Episode 1 (utterances 23-24)
- Episode 2 (utterances 42-48)
- Episode 3 (utterances 52-56)
- Episode 4 (utterances 57-59)
- Episode 5 (utterances 67-79) in Appendix 8xix
- Episode 6 (utterances 80-81) in Appendix 8xx

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video

- Episode 1 (utterances 9-16)
- Episode 2 (utterance 21) in Appendix 8xxxi
- Episode 3 (utterances 27-29)
- Episode 4 (utterances 51-58) in Appendix 8xxxiii
- Episode 5 (utterances 59-68) in Appendix 8xxxiv
- Episode 6 (utterances 119-123)
- Episode 7 (utterance 123) in Appendix 8x
- Episode 8 (utterances 137-138) in Appendix 8xxx
- Episode 9 (utterances 148-159) in Appendix 8xii
- Episode 10 (utterances 191-199)
- Episode 11 (utterances 224-231)
- Episode 12 (utterances 241-248)
- Episode 13 (utterances 384-386)
- Episode 14 (utterances 398-402) in Appendix 8ix
- Episode 15 (utterances 445-452)

Event 17, Jan 17th 2006, Austpark, Jakob, Cabri, Computer lab, Video

- Episode 1 (utterances 76-83)

Event 18, Jan 18th 2006, Austpark, Frode, Compasses, Classroom, Audio

- Episode 1 (utterances 12-14) in Appendix 8xiv
- Episode 2 (utterances 39-51)
- Episode 3 (utterances 87-100) in Appendix 8xxiii

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio

- Episode 1 (utterance 1)
- Episode 2 (utterances 5-7) in Appendix 8xxii
- Episode 3 (utterances 14-17) in Appendix 8xxiv
- Episode 4 (utterances 18-20)
- Episode 5 (utterances 31-32)

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video

- Episode 1 (utterances 172-176)
- Episode 2 (utterance 176)
- Episode 3 (utterances 176-178)
- Episode 4 (utterance 178)
- Episode 5 (utterance 183) in Appendix 8ii
- Episode 6 (utterances 187-192) in Appendix 8xxv

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom, Video

- Episode 1 (utterances 123-129)
- Episode 2 (utterances 143-147) in Appendix 8xxxii
- Episode 3 (utterances 155-159)
- Episode 4 (utterances 163-167)
- Episode 5 (utterances 320-321)
- Episode 6 (utterance 357)

Event 23, Jan 20th 2006, Fjellet, Trude, Cabri, Conversation, Audio

- Episode 1 (utterances 45-53)
- Episode 2 (utterances 63-65)

Event 25, Feb 7th 2006, Austpark, Jakob, Cabri, Classroom, Video

- Episode 1 (utterances 16-22) in Appendix 8xvi
- Episode 2 (utterances 22-25) in Appendix 8xviii
- Episode 3 (utterances 118-128) in Appendix 8xvii
- Episode 4 (utterance 134)

Event 27, Feb 7th 2006, Austpark, Frode, Cabri, Conversation, Audio

- Episode 1 (utterance 3)
- Episode 2 (utterances 9-15)

Event 28, Feb 15th 2006, Austpark, Frode, Cabri, Computer lab, Video

- Episode 1 (utterances 25-27)
- Episode 2 (utterance 67)

Event 29, Feb 21st 2006, Austpark, Jakob, Excel, Computer lab, Video

- Episode 1 (utterance 16)
- Episode 2 (utterances 34-38) in Appendix 8xxi

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video

- Episode 1 (utterances 20-22)
- Episode 2 (utterances 80-83)
- Episode 3 (utterances 85-87)
- Episode 4 (utterances 92-95) in Appendix 8xxvii
- Episode 5 (utterances 120-127)
- Episode 6 (utterances 153-156)
- Episode 7 (utterances 197-199) in Appendix 8xxxv
- Episode 8 (utterances 307-317) in Appendix 8xxviii
- Episode 9 (utterances 349-359)
- Episode 10 (utterances 426-429)
- Episode 11 (utterances 465-470)

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio

- Episode 1 (utterances 39-53)
- Episode 2 (utterances 54-56)
- Episode 3 (utterances 62-63)
- Episode 4 (utterances 67-74) in Appendix 8iii
- Episode 5 (utterances 81-83)
- Episode 6 (utterances 84-87) in Appendix 8iv
- Episode 7 (utterances 88-92)
- Episode 8 (utterances 112-116)
- Episode 9 (utterances 166-175) in Appendix 8viii
- Episode 10 (utterances 175-181)
- Episode 11 (utterances 275-282)
- Episode 12 (utterances 433-437) in Appendix 8xv
- Episode 13 (utterances 506-511) in Appendix 8xxvi
- Episode 14 (utterances 531-536)
- Episode 15 (utterances 624-628)
- Episode 16 (utterances 632-637)

Event 33, Mar 10th 2006, Fjellet, Trude, Cabri, Conversation, Audio

- Episode 1 (utterances 35-41) in Appendix 8xxxvi
- Episode 2 (utterances 106-114)

Event 34, Mar 23th 2006, Fjellet, LCM focus group interview, Audio

- Episode 1 (utterance 15)

Event 35, Mar 29th 2006, Austpark, LCM focus group interview, Audio

- Episode 1 (utterances 35-38)
- Episode 2 (utterances 40-45)
- Episode 3 (utterances 64-71) in Appendix 8xxxvii
- Episode 4 (utterances 215-218)

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video

- Episode 1 (utterances 12-13)
- Episode 2 (utterance 23) in Appendix 8xiii
- Episode 3 (utterance 33)
- Episode 4 (utterances 36-45)
- Episode 5 (utterances 45-48) in Appendix 8vii
- Episode 6 (utterance 55) in Appendix 8xi
- Episode 7 (utterance 79)
- Episode 8 (utterances 79-82)
- Episode 9 (utterances 136-139) in Appendix 8xxix
- Episode 10 (utterances 140-142)

Event 39, Nov 29th 2006, UiA, ICTML Workshop 10, Video

- Episode 1 (utterance 38)
- Episode 2 (utterance 40)

Event 43, Jan 17th 2008, Fjellet, Trude, e-mail responses, Audio

- Episode 1
- Episode 2

Event 44, Jan 22nd 2008, Aud, End of ICTML project interview, Audio

- Episode 1 (utterance 24)
- Episode 2 (utterance 24) in Appendix 8i
- Episode 3 (utterance 26)
- Episode 4 (utterance 52)

Appendix 8 Additional episodes

Below is a list of transcripts. Below each transcript, the numbered event and episode refers to the list of events (see Appendix 1) and the list of episodes and utterances from each event (see Appendix 7) in the case study. The episodes below are not presented *inside* the chapters of the thesis but are additional episodes which are quoted in the thesis to complement or supplement statements such as the quote to Appendix 8i on page 136. The list of episodes below is made chronologically based on where in the thesis I refer to the episodes starting with Appendix 8i.

Appendix 8i

Ut	Who	What is said (translation)	What is said (original)
24	Aud	… What he had at Austpark (refers to the workshop session for all the teachers, see Event 13) was supposed to be planning but turned out to rather be a course ran with the teachers to motivate and develop their competences in Cabri.	…Det som han hadde på Austpark (*referer til en verkstedsamling for alle lærene, se Event 13*) var jo ment å være mer planlegging men det ble i større grad et kurs opplegg som han kjørte med de lærerne for å motivere de og få de godt inn i Cabri programmet.

Event 44, Jan 22nd 2008, Aud, End of ICTML project interview, Audio, Episode 2

Appendix 8ii

Ut	Who	What is said (translation)	What is said (original)
183	Jakob	We are also teaching at Grade 8 and we were lucky to have Otto who came and held a course for us in Cabri…	Vi også er i åttende klasse og vi var heldige og fikk Otto til å komme og så holde kurs for oss i Cabri…

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 5

Appendix 8iii

Ut	Who	What is said (translation)	What is said (original)
67	Jakob	I think it was based on what we experienced in	Det var vel også når vi var på det her med
68		[KUL]	[KUL]
69	Harald	[Yes]	[Ja]
70	Jakob	(…) and then we had a little geometry (*refers to ICTML workshops where use of Cabri in geometry teaching had been discussed*) .Then I think we had a meeting with you and Otto took also part. Then we could have him here	(…) og så hadde vi vel litt om geometri (*her viser han til IKTML workshoper hvor bruk av Cabri i geometriundervisning ble diskutert*). Så tror jeg vi hadde møte med dere og Otto var med. Så var det å kunne få ham hit
71	Harald	[Yes]	[Ja]
72	Jakob	[and to conduct such a]	[og så holde et sånn]
73	Harald	[Yes, that is true]	[Ja. Stemmer]
74	Jakob	course for the teachers	kurs for lærerne

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 4

Appendix 8iv

Ut	Who	What is said (translation)	What is said (original)
84	Harald	Because to have Otto here was good. Well it is important with with this basis	For det å få Otto her det var jo bra. Altså det er viktig med den den basis
85		[(…)]	[(…)]
86	Ingvald	[Yes]	[Ja]
87	Harald	to get going, yes	komme i gang, ja

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 6

Appendix 8v

Ut	Who	What is said (translation)	What is said (original)
141	Frode	[I would have applied my own teaching plan and used the teaching package Jakob has received from his colleague.]	[Jeg ville ha kjørt et eget opplegg og ville brukt det Jakob har fått fra han kameraten din.]
142	Jakob	[Yes]	[Ja]
143	Frode	It is a kind of, call it basic course in Cabri	Det er et sånt, kall det grunnkurs i Cabri
144	Harald	[Okay]	[Okey]
145	Frode	with five lessons.	med fem leksjoner.
146	Jakob	Yes, it is someone I have been studying together with, who now works at a lower secondary school; he has designed his own course package in Cabri. I think it is five (*refers to the number of worksheets in the written teaching package*)	Ja, en har jeg har student med som jobber på en ungdomsskole, han har laget et eget kursopplegg i Cabri. Jeg tror det er fem (*referer til antall arbeidsark i kursopplegget*)
147	Frode	[Yes]	[Ja]
148	Jakob	with constructions	med konstruksjoner
149	Frode	I think we potentially can apply the teaching package directly in teaching at the grade (*he meant Grade 8*). As a start.	Det tror jeg vi kunne ha kjørt nesten bare på trinnet altså (*mener åttende trinn).* Som en start.
150	Jakob	[Mm]	[Mm]
151	Frode	In order to come to know the software and all the concepts it offers. And then we rather could look into things in common on all the grades.	For å bli kjent med programmet og alle begrepene der. Og så kunne en heller gå inn og se på ting som er knyttet til fellesting vi skal ha på hvert trinn.
152	Jakob	[Mm]	[Mm]
153	Harald	But will we be able to, to use the computer lab as much as this? Well, that's it.	Men klarer vi å få det til, å bruke datarommet så mye. Ja det var det.
154	Jakob	I just think we have to make a copy of the plan (*refers to booking of the computer lab*) and sit down together and share the lab as brothers and sisters.	Tror vi får bare ta kopi av den planen (*refererer til bestilling av datalab*) og sette oss ned sammen og fordele broderlig, søsterlig.
155	Harald	Okay. Then we start off with those tasks.	Okey. Da prøver vi oss i gang med de oppgavene der.
156	Frode	Mm	Mm

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 9

Appendix 8vi

Ut	Who	What is said (translation)	What is said (original)
12	Gunnar	I had a meeting with the principal and said that they had to put priority to our use of Cabri on the computer lab after Christmas	Jeg var inne hos rektor hvert fall og sa fra at, at det må tas hensyn til at vi skal bruke datarommet til Cabri etter jul.
13	Aud	[Yes]	[Ja]
14	Harald	put us highest (*refers to the booking list for the computer labs*). In order to have access. And he did write it down, he did so. He could not do so much more at that moment except for this enterprise.	plassere oss høyest (*refererer til bestillingslista for data labben*). Få tid dere inne. Og det noterte han ned, han noterte det hvert fall opp. Han kunne ikke gjøre noe særlig mer akkurat da så har hvert fall det lille grepet her.
15	Frode	At least he wrote it down	Han skrev det hvert fall ned
16	Gunnar	Yes. It was meant for the planning committee and like so	Ja. Det var jo til plankomiteen og litt sånne ting
17	Some	[Mm]	[Mm]
18	Gunnar	Well, but anyway we have made it clear that we want priority on it. It is a matter that in order to use it there need to be some regularity.	Men hvert fall, vi får den at vi får kjørt fram at det skal ha litt prioritet. Det er også noe med at hvis vi skal jobbe med det må vi også ha litt kontinuitet på det her.

Event 12, Dec 7th 2005, Austpark, School team meeting, Audio, Episode 1

Appendix 8vii

Ut	Who	What is said (translation)	What is said (original)
45	Jakob	…We reserved time at the computer lab for all classes at the school.	…Vi satte av tid på datarommet for alle klassene på skolen.
46	Frode	Yes	Ja
47	Jakob	And that about the organising, and that we actually made the effort and wrote our names and the number of teachers on the room, made an emphasis on it.	Og det med organiseringen, og at vi faktisk gjorde den satsningen og skrev oss opp og skrev opp antall lærere på rommet, gjorde at vi da fikk et trykk på det da.
48	Frode	We pushed ourselves to put emphasis on it	Vi tvang oss selv til å satse på det

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 5

Appendix 8viii

Ut	Who	What is said (translation)	What is said (original)
166	Jakob	[It was something which]	[Det var noe som]
167	Jakob	Bueie had developed	han Bueie hadde utviklet
168	Ingvald	[Mm]	[Mm]
169	Jakob	I thought looked appropriate to use	som jeg syntes virket greit å bruke.
170	Ingvald	Yes	Ja
171	Jakob	At the start, in the early phase of working with Cabri. Because I do not know my students as independent to any great extent. It is something I have to work on with the class to have them more independent.	Sånn til å begynne starte opp med Cabri. For jeg kjenner ikke elevene mine som veldig selvstendige enda. Det er noe som jeg må jobbe med den klassen og få de til å bli mer selvstendige.

172	Ingvald	Yes	Ja
173	Jakob	Throw themselves in such, yes such more investigative tasks and problem solving tasks, and work more in groups. I do not think they are so clever at this yet.	Hive seg på sånne, ja litt mer sånn utforskende oppgaver og problemløsningsoppgaver, og jobbe litt mer i gruppe. Jeg synes ikke de er så veldig flinke til det enda.
174	Ingvald	No	Nei
175	Jakob	But I thought they were very concrete and suitable the tasks which Bueie had developed …	Men jeg syntes de var veldig konkrete og greie de oppgavene som Bueie hadde utviklet. …

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 9

Appendix 8ix

Ut	Who	What is said (translation)	What is said (original)
398	Jakob	He has also included the curriculum, because I looked through the textbook and he has included the curriculum at Grade 8 in his sheets	Han har også lagt pensumet for jeg kikket igjennom boka og han har lagt pensumet for geometri i åttende klasse inn i de kursarkene som han har da.
399	Trude	[Oh, yes]	[Å ja]
400	Some	[Mm.]	[Mm.]
401	Trude	that was really clever	det var kjempesmart.
402	Jakob	The only thing he lacks is the symmetry, there I will be using something which Otto have in his sheets	Eneste han mangler er symmetrien der vil jeg bruke noe som Otto har på sine ark, han hadde noe.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 14

Appendix 8x

Ut	Who	What is said (translation)	What is said (original)
123	Frode	… and I too feel that I have to proceed tentatively together with the students and use some readymade sheets.	… og jeg også føler meg litt sånn at jeg må prøve meg fram sammen med elevene og de bruker noen ferdige ark.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 7

Appendix 8xi

Ut	Who	What is said (translation)	What is said (original)
55	Jakob	Those sheets which Bueie has made are really self-explanatory and simple. The reason why we chose to make it so simple and self-explanatory is partly because of our own security as teachers. It was not too gloomy to start on. Those of us who participate in the KUL project (*means LCM and/or ICTML*) have some experience with Cabri, but also the other teachers have experienced it as not being to gloomy to start implement. They experienced that it was quite autonomous.	De arbeidsarkene som Bueie har laget er veldig selvforklarende og enkle. Grunnen til at vi har valgt å gjøre det så enkelt og selvforklarende er litt for vår egen trygghet som lærere. Det var ikke så skummelt å sette i gang. Nå har jo vi som har vært med i KUL-prosjektet (*mener LCM og/eller ICTML*) har jo fått en del erfaring etter hvert med Cabri, men de andre lærerne har heller ikke erfart det så skummelt å sette i gang- De opplevde at det gikk ganske av seg selv.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 6

Appendix 8xii

Ut	Who	What is said (translation)	What is said (original)
148	Jakob	Those sheets are extremely	De arkene er veldig
149	Jakob	[such step by step alike]	[sånn steg for steg aktig.]
150	Frode	[Mm, mm, yes, mm]	[Mm, mm, yes, mm]
151	Trude	Oh, yes	Å ja
152	Jakob	So it is meant a bit like to learn to use the tool and that they are supposed to be self-going on	Så det er de er ment litt på å lære verktøyet og at de skal være litt sånn selvdrevne på
153	Frode	[Yes]	[Ja]
154	Jakob	experiencing the different things with the tool. So they are fairly such step [by step]	å komme bort i de forskjellige tingene med verktøyet. Så de er veldig sånn steg [for steg]
155	Some	[Mm]	[Mm]
156	Jakob	so it works really quite well to be teacher and walk around and [assist those who need it]	så det går egentlig veldig greit å være en lærer som går rundt og [hjelpe de som trenger det.]
157	Frode	[Mm, mm]	[Mm, mm]
158	Frode	Mm	Mm
159	Jakob	That is at least my view.	Synes jeg da

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 9

Appendix 8xiii

Ut	Who	What is said (translation)	What is said (original)
23	Jakob	We have perhaps not implemented so much of those inquiry-tasks which we received from KUL in what we have ran on Grade 8. That is partly because the Cabri software we are using is new for some of the teachers, it is new for the students, and we found out that the students starts with little knowledge of geometry when they start at Grade 8. So we spent time on the tool and the basic things.	Vi har ikke kanskje implementert så mye av de inquiry-oppgavene som vi har fått på, fra KUL så mye i dette som vi har kjørt i åttende trinn. Det har litt med at Cabri-programmet vi bruker er nytt for en del lærere, og det er nytt for elevene, og egentlig så fant vi ut at elevene startet jo med ganske lite i bagasjen når de begynner med geometri i åttende trinn. Så vi brukte tid på verktøy og grunnleggende.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 2

Appendix 8xiv

Ut	Who	What is said (translation)	What is said (original)
12	Frode	All of you. What we will do today is connected. Because we will do the same in textbook and Cabri	Dere. Det vi skal gjøre i dag, det henger sammen. For vi skal gjøre det samme i boka og i Cabri.
13	Student	Ohh!	Øhh!
14	Frode	I will show you four things first. First I present, afterwards you are supposed to the same (*noise, 12 seconds*) Ready? (*noise, 15 seconds*). Apply the rulebook and write the heading Perpendiculars.	Jeg skal vise dere fire ting først. Jeg viser først, så skal dere prøve å gjøre det samme etterpå. (*støy 12 sekunder*) Klare? (*støy, 15 sekunder*) Bruk regelboka og skriv overskriften Normaler

Event 18, Jan 18th 2006, Austpark, Frode, Compasses, Classroom, Audio, Episode 1

Appendix 8xv

Ut	Who	What is said (translation)	What is said (original)
433	Frode	And almost all of them replied with a yes, that they understood better when using both Cabri and compass. Only very few have replied no: I wish I only could be using compass. Or only use Cabri. But that are really very few, more than 90 percent are satisfied that we ran both. So there are not many who have written that they only wanted Cabri.	Og svarer nesten alle ja jeg forsto egentlig bedre der vi brukte både Cabri og passer og linjal. Så er det noen få som har svart nei: jeg skulle ønske jeg bare brukte passer og linjal. Eller bare brukte Cabri. Men det er så få at, ja godt over nitti prosent som er fornøyd med at og så kjøre begge deler. Det er ikke mange som har skrevet at de ville bare ha Cabri.
434	Ingvald	No	Nei
435	Frode	They wanted to have both.	De ville ha begge deler altså.
436	Ingvald	Mm.	Mm.
437	Frode	Mm.	Mm.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 12

Appendix 8xvi

Ut	Who	What is said (translation)	What is said (original)
16	Jakob	… Then it is [point] b). Construct a perpendicular on *k*, hence on the line in the point *P*. (…) *P*. Then I start off with a circle. Pointing on the point there, drag it out a bit like so	… . Så er det [punkt] b). Opprett en normal på *k*, altså på linja i punktet *P*. (…) *P*. Da begynner jeg med en sirkel. Peker på punktet der, drar den ut litte grann sånn.
17	Karl	Then you have done it?	Så har du gjort det?
18	Jakob	No. Now I have, now I have made the start. Now I have the points which are placed in equal distance from *P*.	Nei. Nå har jeg nå har jeg begynnelsen. Nå har jeg de punktene som ligger like langt i fra *P*.
19	Jakob	Yes, and then you drag it over (*Jakob refers to how he during the construction of the new circle with radius twice the size of the first circle, moves the mouse pointer all the way down to the intersection between the line k and the first circle*)	Ja og så drar du den over (*Jakob viser til hvordan han under konstruksjon av den nye sirkelen med dobbel så stor radius som den første beveger musepekeren over til skjæringspunktet mellom linja k og den første sirkelen*)
20	Jakob	And then I drag it over there (*see the comment in utterance 19*). The reason why I move it all the way and this is **really** important. Many of you have done this wrong	Og så tar jeg den over der (*se kommentar i uttalelse 20*). Grunnen til at jeg tar helt over og det dette er **veldig** viktig. Dette er det mange som har gjort feil.
21	Ivar	Because they (…) ninety degree?	Fordi de (…) nitti grader?

22	Jakob	I can not just aim for the point. Can you see that I know have my pencil. I point with my pencil up there (*Jakob moves from the machine up to the screen in front of the room and points with his finger on the mouse pointer*). It appears like it hits well there. So one should assume that this will go well. And perhaps it should too, but it does not! It is really important that I point with my pencil where I want it (*refers to the circle*) to intersect. Then you have to go down to, when this to this intersection point arrives (*refers to "to this circumference point" which arrives on the screen when the mouse pointer is moved near the point*) it is time to click. …	Jeg kan ikke bare sikte på punktet. Ser dere at jeg nå har blyanten min. Så peker jeg med den blyanten her oppe (*Jakob beveger seg fra maskinen fram til lerretet og peker med fingeren på musepekeren*). Det ser ut som den treffer bra der. Så i utgangspunktet skulle en tro at dette her går jo fint. Og det burde det kanskje også men det gjør det ikke! Det er veldig viktig at jeg peker med blyanten der som jeg vil at den (*viser til sirkelen*) skal skjære. Da må du ta ned til, dette når det kommer opp dette skjæringspunktet (*viser til "Dette punktet på sirkelen" som dukker opp på skjermen når musepeker beveges nær punktet*) så kan du trykke. …

Event 25, Feb 7th 2006, Austpark, Jakob, Cabri, Classroom, Video, Episode 1

Appendix 8xvii

Ut	Who	What is said (translation)	What is said (original)
118	Jakob	And then we must construct a 60 degree angle in *A*. And we name the new line which we have *q*. So we are supposed to construct a 60 degree angle in *A*.	Og så skal vi konstruere en vinkel på seksti grader i *A*. Og vi skal kalle den nye linja som vi får der for *q*. Så vi skal altså konstruere en seksti graders vinkel i *A*.
119	Karl	Isn't it like [this?]	Er ikke det noe [sånn?]
120	Jakob	[Yes]	[Ja.]
121	Karl	and then back again? (*Karl quickly accomplish the construction of 60 degree angle in Cabri*)	og så går den tilbake igjen? (*Karl utfører raskt konstruksjon av 60 graders vinkel i Cabri*)
122	Jakob	Yes. Now you have constructed two circles which have exactly the same size. Yes, if you click there. And the line passing through *A* and then the intersection point between the two circles.	Ja. Det som du gjør nå er at du konstruerer to sirkler som er akkurat like store. Ja, hvis du klikker der. Og den linja som går gjennom *A* og så skjæringspunktet mellom de to sirklene.
123	Karl	Mm. Do you want me to do it?	Mm. Ja skal jeg gjøre det?
124	Jakob	Yes. And the through the intersection point. That angle there.	Ja. Og så s igjennom skjæringspunktet. Den vinkelen her.
125	Karl	It is 60.	Den er 60.
126	Jakob	It is 60 degree. (*9 seconds*). 60 degree. So if you move the pointer and drag a bit there, the point in the point there.	Den er 60 grader. (*9 sekunder*) 60 grader. Så hvis du legger pekeren og så drar du litt i det der, punktet i det punktet der.
127	Karl	There?	Der?
128	Jakob	Yes. If you drag there you will see that the circles get bigger, but the angle will in any case be the same!	Ja. Hvis du drar det så ser du at sirklene blir større, men uansett så er vinkelen den samme!

Event 25, Feb 7th 2006, Austpark, Jakob, Cabri, Classroom, Video, Episode 3

Appendix 8xviii

Ut	Who	What is said (translation)	What is said (original)
22	Jakob	... Can you see how it (*refers to the circumference of the circle*) was connected to the intersection point? So if you now start to drag in the little circle. Yes now you first select that one. This intersection point. Yes. If you now drag that one, click on that one there and then the little circle here (*Jakob points on the picture of the screen appearing on the video screen*). And then drag it a bit up and down	… Ser du så bandt den (*referer til sirkelperiferien*) seg bort til det skjæringspunktet? Så hvis du nå tar tak i den der lille sirkelen. Ja nå tar du først den ja. Dette skjæringspunktet. Ja. Hvis du nå tar tak i den, trykker på den der der og så tar du tak i den lille sirkelen her (*Jakob peker på bildet av skjermen på lerettet*). Og så drar du den litt opp og ned.
23	Karl	Holding (…)	Holder (…)
24	Leiv	(…)	(…)
25	Jakob	Click, click on pointer while you drag. No, you did not manage to do it (*Jakob communicates with Karl who controls the mouse pointer in Cabri*). Yes you have to, have to drag in that one I think because I connected it to that point (*refers to the figure in Cabri and which parts that are constructed and not*). Then you drag it. Look, they are connected. And this is really such an important check to do. Is it all moving together? If it is connected, then you have probably constructed it correctly.	Hold, hold inne pekeren mens du drar. Nei det fikk du ikke til. (*Jakob snakker med Karl som styrer musepekeren i Cabri*) Ja du må, må hvis dra i den for jeg, jeg tror jeg bandt den til dette punktet (*viser til figuren i Cabri og hvilke deler som er konstruerte og ikke*). Så drar du. Se nå henger de sammen. Og det er en veldig sånn viktig sjekk og gjøre. Henger dette her sammen? Hvis det henger sammen da har dere sannsynligvis konstruert det riktig.

Event 25, Feb 7th 2006, Austpark, Jakob, Cabri, Classroom, Video, Episode 2

Appendix 8xix

Ut	Who	What is said (translation)	What is said (original)
67	Jakob	If you select the one with the label Calculate on the third from the right (*refers to the menu bar in Cabri*). Then such a thing turn up on you screen (*The Calculate window appear*)	Hvis dere går inn på den som heter Beregn på den tredje fra høyre (*viser til menyraden i Cabri*). Så kommer det opp en sånn sak her nede (*Kalkualtor-boks*).
68	Karl	Yes	Ja
69	Jakob	Then I first click on one of the numbers	Så klikker jeg først på det ene tallet.
70	Karl	Yes	Ja
71	Jakob	Then I click on the add (*refers to add symbol in the Calculate window*) which I find underneath here	Så trykker jeg på pluss (*viser til symbolet for pluss som de finner i Beregn-vinduet*) og det finner jeg her nede.
72	Karl	[What did you say?]	[Hva sa du?]

73	Jakob	Now I will do it a bit slower. First we have to bring up Calculate (*refers to the Calculate option in the menu bar*)	Nå skal jeg gjøre det litt saktere. Vi skal først gjøre så vi får opp den her Beregn (*viser til Beregn valget i menyraden*)
74	Mats	Yes, where is it placed?	Ja, hvor star den henne?
75	Jakob	It is up here (*refers to the Calculate option in the menu bar*)	Den står her oppe (*viser til menyraden i Cabri*)
76	Mats	We do not have it	Vi har ikke den
77	Jakob	Indeed, on the third from the right. Then I click on the first number, then on the plus, next I click on the second number, then on the plus, next on the third number, and then I click on the equal	Jo, den tredje fra høyre. Så trykker jeg på det ene tallet, så på pluss, så det andre tallet, så trykker jeg på pluss, så trykker jeg på det tredje tallet, så trykker jeg erlik.
78	Mats	Then I got 296	Da fikk jeg 296
79	Jakob	Then you have not done it completely correct. If you look here you can see that I got 180 down here. What I can do now is to drag in it. Can you see that I get a hand there (*…, much noise, several students try to manage to do it. (Jakob moves to a couple of his students trying to assist them This period lasts for about 35 seconds)*. Have everyone managed it now? (*5 seconds*)	Da har du ikke gjort det helt korrekt. Hvis dere ser da fikk jeg 180 her nede. Det jeg kan gjøre nå er at jeg kan dra den. Ser dere at jeg får en hånd der (*mye støy*, *elevene prøver å få det til*). (*Jakob går rundt og prøver å hjelpe elevene litt. Perioden varer i cirka 35 sekunder)* Har alle fått det til nå? (*5 sekunder)*.

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 5

Appendix 8xx

Ut	**Who**	**What is said (translation)**	**What is said (original)**
80	Jakob	I just want to show you one more thing. Just for you who have managed it. This result here is always the sum of those three. So if you choose the arrow (*refers to how the mouse pointer appears at the screen*) and pull in one of the corners the result will still be the same. You are welcome to try that out (*85 seconds)*	Jeg skal bare vise en ting. For dere som har fått det til. Dette resultatet her er alltid summen av de tre. Så hvis dere velger pila (*viser til hvordan musepekeren ser ut på skjermen*) og drar i et av hjørnene blir resultatet hele tiden det samme. Dette kan dere godt prøve litt på. (*85 sekunder)*
81	Jakob	This shows, regardless **regardless** of the form of the triangle, the sum of the size of its angles is 180 degree, neither more nor less.	Dette viser, uansett **uansett** hvordan trekanten ser ut er vinkel summen 180 grader, verken mer eller mindre.

Event 15, Jan 10th 2006, Austpark, Jakob, Cabri, Computer lab, Audio, Episode 6

Appendix 8xxi

Ut	Who	What is said (translation)	What is said (original)
34	Jakob	Now I think I will go through the formulas you are supposed to use. Can you see what is written here? (*Increases the screen window, some interruptions, 24 seconds).* What I will do now, this balance. The first balance here, what is written on the first line (*refers to the text placed in the first row underneath the heading "Item" named "Monet in the pot"*). We write: Money in the pot, when we start the spreadsheet, saying it is an income. In a way it is the money we have in our hand or in the bank. Then we write it as an income and we also write it as balance. So the first formula there, can you see what it will be? =E7 (*writes =E7 in the first row beneath the "Balance" heading*). Then we write =E7 which means that we can see over there how much our income is all the time (…). Okay, if I change 5000 to 4500 over there (*refers to the income cell*), what will happen over (*refers to the balance cell*) there?	Nå tror jeg at jeg skal gå gjennom de formlene dere skal bruke. Ser dere det som står her? (*Forstørrer skjermbildet, diverse små avbrytelser fra elevene, 24 sekunder*). Det jeg skal gjøre nå, denne her saldoen. Den første saldoen her, det som står på denne linja (*viser til teksten på første item i budsjettet kalt "Penger i kassa*") Penger i kassa, fører vi, når vi starter med regnearket sier vi at det er en inntekt. Da er det på en måte de pengene vi får i hånda, eller har i banken. Da fører vi det som en inntekt og det fører vi også som saldo. Så den første formelen der, ser da hva den er for noe? =E7 (*skriver =E7 i første celleunder overskriften saldo*). Da skriver vi =E7 det betyr at den her borte følger med på hvor mye vi har i inntekt hele tida. (…) Okey, hvis jeg forandrer 5000 til 4500 her borte (*viser til inntektscella*), hva tror dere skjer her borte (*viser til saldocella*) da?
35	Rune	4500	4500
36	Jakob	Then it changes that one too	Da forandrer den seg også.
37	Mari	What were we supposed to write there?	Hva var det vi skulle skrive der borte?
38	Jakob	There you write = the cell there, in this instance it is =E7. But maybe you will have something else than E7, so you have to (…)	Der skriver du = den cella der, i dette tilfellet er det =E7. Det kan godt være dere har noe annet enn E7, det må dere (..)

Event 29, Feb 21st 2006, Austpark, Jakob, Excel, Computer lab, Video, Episode 2

Appendix 8xxii

Ut	Who	What is said (translation)	What is said (original)
5	Frode	Choose "Text" (*named "Skriv kommentar" (Write comment) in the Norwegian version of Cabri*) and then we write Perpendiculars (*he speaks with a loud voice level followed by a 20 seconds pause*). One more comment (*refers to choosing "Text"*), we write "a) To a point on a line". (*15 seconds*). Finished?	Gå på "Skriv kommentarer" (*kalles "Skriv kommentar" i den norske utgaven av Cabri*) og skriv vi "Normaler" (*han snakker høyt fulgt av 20 sekunders pause*). En kommentar til, vi skriver "a) Til et punkt på ei linje", til et punkt på ei linje. (*15 sekunder*). Ferdig?
6	Tron	Yes sir	Yes sir

7	Frode	Now we must make a line. We are supposed to have a line, not a segment. A line. Starting approximately here, choosing line and a point	Nå skal vi ha ei linje. Nå skal vi ha ei linje og ikke et linjestykke. Ei linje. Starter sånn ca her, velger linje og et punkt

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio, Episode 2

Appendix 8xxiii

Ut	**Who**	**What is said (translation)**	**What is said (original)**
87	Mons	You need another point	Du må jo ha et punkt (*til*)
88	Frode	Yes, how can I make a point?	Ja, hvordan kan jeg få et punkt
89	Ivan	Half (…)	Halve (…)
90	Frode	It is not without reasons I made that segment (*interrupted*)	Det er ikke uten grunn at jeg har laget det linjestykket (*avbrytes*)
91	Ivan	[You have to make half moons on each side]	[Du må lage halvmåner på begge sider]
92	Frode	A half moon.. That I make a half moon like this (*makes an arch with the compass which has its centre in the point outside the line segment which intersect the line segment two places*)	En halvmåne. At jeg lager en halvmåne sånn (*slår en bue med passeren som har sentrum i punktet utenfor linjestykket og som skjærer linjestykket to steder*)
93	Ivan	Over to the other side	Over på den andre sida
94	Frode	And then over here. Like so.	Og så bort her. Sånn.
95	Ivan	Then you have a point	Da har du et punkt
96	Frode	Then I have a point there too (*places the tip of the compass in the two intersection points on the segment, makes two small arches meeting in a intersection point below the segment*)	Da har jeg et punkt der også (*setter passerspissen i de to skjæringspunktene med linjestykket og lager to små buer som danner et skjæringspunkt nedenfor linjestykket*)
97	Atle	You are a genious	Du er genial
98	Frode	You are a genious, Ivan! Well, we do not use the concept half moon, but okay. It is a part of a circle, an arc. Excellent. Then we have another point.	Du er genial Ivan! Nå bruker ikke vi begrepet halvmåne men okey. Det er en del av en sirkel, en bue. Flott. Da har du et punkt til.
99	Ivan	Yes, yes	Jau, jau
100	Frode	Up there and down here. We apply the ruler and make a line. Then we have managed to make a perpendicular down to a segment.	Der oppe og her nede. Bruker linjalen og trekker opp linja. Da har vi opprettet en normal til et linjestykke.

Event 18, Jan 18th 2006, Austpark, Frode, Compass, Classroom, Audio, Episode 3

Appendix 8xxiv

Ut	Who	What is said (translation)	What is said (original)
14	Frode	What did we do, we had a line and a point which we named A. And then we were supposed to make a perpendicular. Knut, how did we do it?	Hva var det vi gjorde for noe, vi hadde ei linje og et punkt vi kalte for A. Og så skulle vi opprette en normal. Knut, hvordan gjorde vi det?
15	Knut	Took a line through the point, or?	Tok ei linje opp fra punktet eller?
16	Frode	A line through the point, yes. How can we guarantee it to be 90 degree? How did we do it on the blackboard?	Ei linje fra punktet, ja. Hvordan skal vi få det garantert 90 grader? Hvordan gjorde vi på tavla?
17	Jarl	[Yes, yes the intersection point]	[Jo, jo skjæringspunkt]

Event 19, Jan 18th 2006, Austpark, Frode, Cabri, Computer lab, Audio, Episode 3

Appendix 8xxv

Ut	Who	What is said (translation)	What is said (original)
187	Jakob	One thing I noticed when walking around at the computer lab and assisted them was a thing which I evidently had not explained. If you have a line and afterwards are supposed to make a circle. In connection with making a perpendicular. The construction of a circle which I explained were supposed to pass through a point on the other circle, many of them only did this (*Jakob illustrates how students only aim at points*).	En ting som jeg la merke til når jeg holdt på med når jeg holdt på å gå rundt og hjelpe dem da var det sånn der ting som jeg tydeligvis ikke hadde forklart før. Hvis vi har ei linje og så skal vi ha en sirkel. I forbindelse med å lage en normal. Konstruere en sirkel så og jeg hadde forklart at den skulle gå igjennom gjennom punktet på den andre sentrum på den andre sirkelen så var det mange som bare gjorde sånn (*Jakob illustrerer hvordan elevene bare sikter på punkt*).
188	Aud	Mm.	Mm.
189	Ingvald	Mm.	Mm.
190	Jakob	So then, yes it does not work, there is something wrong with the software! (*refers to students comments*)	Så da, ja det virker jo ikke, det er noe galt med programmet! (*viser til hvordan elevene reagerer*)
191	Several	(*Laughter*)	(*Latter*)
192	Jakob	So that was fairly typical, yes. Then I had to show them in plenary because so many of them had not grasped that they had to apply the pointer, use the pencil (…), the pointer which is gluing it together what were supposed to be glued together and then it worked. But this was something which I had not considered and thought of being obvious, but it was not.	Så det var en sånn typisk, ja. Da måtte jeg opp og så ta felles for det så jeg det var mange som mange som ikke hadde fått med seg at de måtte bruke den pekeren da bruke blyanten (…) pekeren at det var den som limte det sammen da det som skulle limes sammen da så da virket det. Men det var sånn som jeg det tenkte jeg ikke på det tenkte jeg var så opplagt, men det var det altså ikke.

Event 21, Jan 18th 2006, UiA, ICTML Workshop 7, Video, Episode 6

Appendix 8xxvi

Ut	Who	What is said (translation)	What is said (original)
506	Jakob	So in order to do problem solving it would be nice to	Så for å drive med problemløsning så er det jo kjekt å
507	Harald	To know it, yes	Kunne det ja.
508	Jakob	[Know (…)]	[Kunne (…)]
509	Harald	[Yes surely. Clearly]	[Ja ja vissst. Helt klart]
510	Jakob	so in a way you know how to apply the tool to solve problems	så på et vis vet hvordan du kan bruke verktøyet til å løse problemer.
511	Harald	Mm.	Mm.

Event 31, Mar 9th 2006, Austpark, End of Cabri-use interview, Audio, Episode 13

Appendix 8xxvii

Ut	Who	What is said (translation)	What is said (original)
92	Jakob	I think after a while they do not have to spend so much time on the tool-technical part. Then perhaps I can give them tasks which are more investigative tasks. I think so.	Jeg tror etter hvert at de ikke trenger å bruke så mye tid på det verktøytekniske. Da kan jeg kanskje gi de oppgaver som er mer utforskende oppgaver. Tror jeg.
93	Otto	Don't you think it is a bigger challenge to go from where you the whole time have got a detailed description on what to do, to find you own approach? That it in fact is a bigger step than to make out all the technical things.	Tror du ikke det er en større utfordring å gå i fra det at du hele tiden har fått en detaljoppskrift på hva du skal gjøre, til det å finne ut av det selv? At det er faktisk en større overgang enn det er å finne ut av de tekniske tingene
94	Jakob	[It will]	[Det blir]
95	Jakob	of course be a challenge too. It will be.	jo selvfølgelig også en utfordring. Det gjør det.

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 4

Appendix 8xxviii

Ut	Who	What is said (translation)	What is said (original)
307	Frode	Yes although they have such sheets	Ja for selv om de har oppgaveark
308	Otto	[Mm]	[Mm]
309	Frode	with some instructions and some	med noen forklaringer og noen
310	Aud	[Yes]	[Ja]
311	Frode	tasks they are supposed to do, there will continually be things they have to find out	oppgaver de skal gjøre så vil det jo hele tiden være ting de må finne ut av.
312	Aud	Yes	Ja.
313	Frode	In such a (*interrupted*)	I en sånn (*avbrytes*)
314	Aud	and that is exactly the thing they	og det er jo nettopp det at de
315	Frode	[Yes, but]	[Ja men]
316	Frode	Clearly it is not a, one can clearly not denote what they work on as open task. It can not be defined as that.	det er klart det er jo ikke en en må ikke kalle det for en åpen oppgave det de holder på med. Det kan det ikke defineres som.
317	Aud	No	Nei

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 8

Appendix 8xxix

Ut	Who	What is said (translation)	What is said (original)
136	Frode	Yes, we received a confirmation that they had achieved the goals we had concerning the curriculum. And that confirms our views too, they do master both Cabri and use or compass and ruler. As mentioned, 85 gave replies on the questionnaire	Ja, vi fikk bekreftet at de hadde oppnådd målene vi hadde i forhold til pensum. Og det er sånn vi opplever det også, at de mestrer, både Cabri og, bruk av passer og linjal. Det var som sagt 85 som svarte på undersøkelsen.
137	Jakob	82 of them mean they now are able to construct 90 degree. And we can see it passes for both Cabri and for compasses and ruler. (*Changes the picture on the screen*). Yes. Then it was the start-up at Grade 9. We wanted to check the influence of their summer vacation. Because then they had been away from this (*viser til bruk av Cabri og passer*).	82 av dem mener de klarer å konstruere 90 grader. Og det ser vi at det gjelder jo både for Cabri og for med passer og linjal. (*Skifter bilde på lerret*). Ja. Så var det oppstart på niende trinn. Vi ønsket å sjekke hva sommerferien hadde gjort. For de hadde jo da vært vekke litt ifra dette her (*refers to use of Cabri and compasses*)
138	Frode	They said that they did not remember anything from primary school, so I wanted to have a control now so we started the first week with a repetition on exactly the same things, 60, 90 degree, bisecting and so on, and it really **sat**. Well we have not any test on it but in my classes I experienced an atmosphere, they asked me about more challenges, we are ready for something more. So, I do think they learnt quite a bit during the period last year and it **sat**. And we do believe that our project was successful; that it resulted in much learning of geometry, the basic.	De sa jo at de ikke husket noen ting fra barneskolen, så jeg ville ha en liten kontroll nå så vi starter den første uka på (…) og så kjører jeg repetisjon på akkurat de samme tingene, 60, 90 grader, halvering og sånn, og det **satt** altså. Nå har vi ikke noen, nå tok vi ikke noen test på det og sånn, men det var sånn der spenning at å kan vi ikke få noe mer utfordringer enn dette her, nå er vi klar for noe annet. Så, jeg tror at perioden i fjor var lærerik for dem og det **satt**. Og vi har jo tro på det at prosjektet var vellykket; at det gjorde at de lærte mye om geometri, det grunnleggende.
139	Jakob	They have learnt to use the tool Cabri; they have also learnt to use compass and ruler. They have learnt to construct perpendiculars, 60 degrees and bisectors, which were what we wanted them to be able to do. Further plan is to perhaps trying to utilise what they have learnt with investigative tasks. That will perhaps be the way ahead.	De har lært å bruke verktøyet, Cabri; de har også lært å bruke passer og linjal. De har lært å konstruere normaler, 60 grader og halvering, det var det vi ville at de skulle sitte igjen med. Nå videre så ser vi at vi kanskje kan bruke det som de har lært nå til litt mer utforskende oppgaver. Det blir vel kanskje veien videre.

Event 38, Sep 5th 2006, Austpark, Conference presentation, Video, Episode 9

Appendix 8xxx

Ut	Who	What is said (translation)	What is said (original)
137	Frode	They do really love it	De synes det er veldig gøy
138	Trude	Yes	Ja

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 8

Appendix 8xxxi

Ut	Who	What is said (translation)	What is said (original)
21	Trude	And I will have two hours (refers to school lessons which usually last for 45 minutes) Frid…, on Fridays two hours from now and all Fridays which are possible before Easter.	Og jeg skal ha to timer (viser til skoletimer som normalt varer i 45 minutt) fred altså fredager i to timer nå utover alle fredager jeg kan helt til påske.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 2

Appendix 8xxxii

Ut	Who	What is said (translation)	What is said (original)
143	Trude	Excellent, yes! These and there. What have you achieved now?	Bravo ja. Der og der. Hva har du fått nå for noe?
144	Emil	What?	Hæ?
145	Trude	What have you achieved now?	Hva har du fått nå for noe?
146	Emil	(…) triangle	(…) trekant
147	Trude	An equilateral triangle. Now you can try to find the symmetry axis. You can, so it can be reflected. How will that be?	En likesidet trekant. Nå skal du ta og finne symmetriakse du kan ta og så det til å speile seg. Åssen går det?

Event 22, Jan 20th 2006, Fjellet, Trude, Cabri, Classroom Video, Episode 2

Appendix 8xxxiii

Ut	Who	What is said (translation)	What is said (original)
51	Trude	But what was quite fun was that they (*refers to the students*) sitting with one machine each	Men det som var litt moro var at de (*referer til elevene*) satt med hver sine maskiner
52	Some	Yes	Ja
53	Trude	and then I told them just to have a go. And they were engaged in it for a while and then I experienced as you (*refers to a statement by Otto*] said	og så sa jeg nå må dere prøve bare. Og så holdt de på å dille med en del ting og så kom som du (*refererer til uttalelse fra Otto*) sa
54	Otto	[Mm]	[Mm]
55	Trude	when some of them started there were others who where a bit smarter, luckily, and brought it to the neighbour (*refers to students sitting next to each other with one laptop each)* and so it spread out and happened to succeed probably with just minor differences millimetre to millimetre differences between the lines (*refers to students constructions of equilateral and isosceles triangles in Cabri*)	Når de noen begynner og så var det en som altså var litt glupere da selvfølgelig heldigvis, og han tok det til naboen (*referer til elevene som sitter ved siden av hverandre med hver sin bærbare PC)* og så spredt spredte det seg og så (…) fikk det til ordentlig det ble litt sånn en millimeter til millimeter forskjell på linjene (*refererer til elevenes konstruksjon av likesider og likebeint trekanter i Cabri*).
56	Ingvald	Mm.	Mm.
57	Trude	And I did not see it right away, so I just told them to look over there and they walked around in the room and it happened to be excellent learning.	Og jeg skjønte ikke og først så sa jeg bare se, titt over der og så gikk de frem og tilbake til hverandre og så var det en kjempefin læring.
58	Ingvald	Mm.	Mm.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 4

Appendix 8xxxiv

Ut	Who	What is said (translation)	What is said (original)
59	Trude	And then I said to them after giving them so help that they should start over again and delete their work.	Og så sa jeg da når de hadde fått litt hjelp da til å få den til begynn å slette alt vekk.
60	Some	Yes	Ja
61	Trude	And then you do it on your own with two different measures	Og så lager du det på egen hånd med først to forskjellige mål
62	Ingvald	[Mm]	[Mm]
63	Trude	which you decide yourself.	som du bestemmer selv.
64	Some	Mm.	Mm.
65	Trude	To show it and then you teach it to the next man (*she refers to how she asked her students to bring their insights to the other students*).	For å vise det og så at du lærer det til neste mann (*hun viser til hvordan hun ba elevene om å forklare til medstudentene*).
66	Some	Mm.	Mm.
67	Trude	So it worked out very well.	Så det funket veldig bra det.
68	Ingvald	Yes, mm.	Ja, mm.

Event 16, Jan 11th 2006, UiA, LCM Workshop 10, Video, Episode 5

Appendix 8xxxv)

Ut	Who	What is said (translation)	What is said (original)
197	Trude	I do it differently. Because they do not receive any sheets to follow. I split the class in two and then half of the class is supposed to work with something they should be capable on and then I concentrated on trying to help the others. They have a machine each. I told them to look at the flip-chart to know what to do. The work was enormous. Last time I used parts in one of Otto's sheet because I had nothing else, the one with polygons and stars.	Jeg gjør det nok annerledes. Fordi de får de ikke noe ark å følge etter. Jeg deler klassen i to og så skal den ene klassen egentlig jobbe med noe som de skulle klare og så skulle jeg prøve å hjelpe de andre. De sitter med hver sin maskin. Jeg sa at de skulle se på flip-overen om hva de skulle finne på. Da var aktiviteten enorm. Forrige gang så tok jeg noe av det s Otto hadde i heftet sitt med for jeg hadde ikke noe annet; den med mangekanter og stjerner.
198	Otto	Mm	Mm
199	Trude	I said to them; if they had questions and I could not manage to assist them sheets were available. You are supposed to make polygons (*Trude talks as if it was the students she talked to*). You are supposed to make figurers inside each other and make stars. It was enormous working effort. They were totally crazy. And I did not stop them. But then I try to stimulate them to think whether they can have other kinds and more. Although I do not succeed in having inquiry as you say, Aud, at least I feel they are going further than I.	Jeg sa til dem; hvis de hadde spørsmål og jeg ikke rakk å hjelpe dem så var arkene der. Dere skal lage mangekanter (*Trude snakker som om hun snakker til elevene*). Dere skal ha figurer inne i hverandre og lage stjerner. Det var en kjempejobbing. De var helt ville. Og det var og så sa jeg altså forskjellige typer. Og jeg stopper dem ikke. Men så prøver jeg og så få dem til å tenke om de kan få flere og andre typer. Så om ikke jeg får til noe inquiry som du sier Aud så føler jeg at de i hvert fall de er mye lenger enn det jeg er..

Event 30, Feb 22nd 2006, UiA, LCM Workshop 11, Video, Episode 7

Appendix 8xxxvi

Ut	Who	What is said (translation)	What is said (original)
35	Trude	If they still not manage to do so very much, at least they dare more now. They had fun today.	Om de ikke klarere all verden så tørr de hvert fall mer nå. For i dag hadde de det moro.
36	Ingvald	Yes indeed	Ja absolutt
37	Trude	And Leah	Og ho Liv
38	Ingvald	Mm.	Mm.
39	Trude	She did it excellent today	ho var kjempegod altså.
40	Ingvald	Yes	Ja
41	Trude	It is fun when a girl succeeds	Det er gøy når en jente får det til

Event 33, Mar 10th 2006, Fjellet, Trude, Cabri, Reflections, Audio, Episode 1

Appendix 8xxxvii

Ut	Who	What is said (translation)	What is said (original)
64	Jakob	I have experienced it as being very interesting to take part in (*refers to the school team*). We can reflect about our teaching. I have found this really all right, and, because I am a very new as teacher and do really appreciate to reflect a bit and share with others	Jeg synes det har vært veldig interessant å være med i (*referere til skoleteamet*). Vi kan reflektere over undervisning. Det synes jeg er veldig ålreit, og, for jeg er veldig fersk som lærer og setter veldig pris på å reflektere litt og dele litt med andre
65	Several	[Mm]	[Mm]
66	Jakob	[and gain from the others]	[og få av andre]
67	Gunnar	And what we can say about the size of the group is that Jakob's entrance and contribution have been very valuable. He has, what we could call, extra competence in many of the things we aspire to at our school. But the fact that we went from being four to be five in the group I think really mattered because it opens up new possibilities for interactions when we got five and not four. Because when you are four and one is absent you are only three and then it is perhaps not so easy to be stimulated.	Og det som vi kan si om gruppestørrelse er at Jakob har vært et veldig verdifullt bidrag. Han har, det vi kan kale, spisskompetanse på mye av de tingene som vi etterstreber på skolen her. Men det at vi gikk fra fire til fem i gruppa tror jeg har veldig mye å si siden det blir større muligheter for interaksjon når vi er fem enn når det er fire. For når du er du fire og en er borte så er du bare tre og da er det kanskje ikke så lett å, å få impulser.
68	Harald	[Mm]	[Mm]
69	Gunnar	If you are five and not four you have greater possibilities to succeed. Well, I think it is important that the size of the group has a certain size; not too small size	Hvis du er fem og ikke fire så har du større muligheter for å få dette her til. Sånn at det er viktig, tror jeg, at en sånn gruppe har en viss størrelse for å være optimal; ikke for liten
70	Harald	[Mm]	[Mm]
71	Gunnar	but neither too big because we are five and that is suitable.	men heller ikke for stor for vi er fem og det tror jeg er sånn passe.

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