# Enhancing Mathematics Learning Through Peer Assessment Using Mobile Tablet Based Solutions

**Ghislain Maurice Norbert Isabwe**

# Enhancing Mathematics Learning Through Peer Assessment Using Mobile Tablet Based Solutions

Doctoral Dissertation for the Degree *Philosophiae Doctor (PhD)* in Information and Communication Technology

University of Agder

Faculty of Engineering and Science

2013

*Seek, and ye shall find.*

<div align="right">—Matthew 7:7</div>

*To my family*

# Preface and Acknowledgments

My interest to do research in the field of Information and Communication Technology goes back to 2007 when I started research work at the Institute of Advanced Telecommunications in Wales (UK). My study focussed on the Data Link layer in wireless communications systems, under the guidance of Dr Kyeong Soo Joseph Kim whom I greatly thank for introducing me to the research community. Although research work at the lower layers of the OSI model is interesting, it gets even more interesting to carry out studies at the top layer, the *Application Layer*, as one deals with application scenarios involving human users. This dissertation is a result of three years of research at the Department of Information and Communication Technology, the Agder Mobility Lab (AML) of the University of Agder (UiA).

This study combines interests into learning of mathematics and mobile services, which require the understanding of pedagogical aspects of learning in technology mediated environments as well as the principles of human computer interaction. Given the broad body of knowledge that was necessary to carry out this research work, it would have been impossible to successfully produce this dissertation without the guidance of my supervisors. My main supervisor has been Professor Frank Reichert, the Dean of the Faculty of Engineering and Science at UiA, and my co-supervisors have been Associate Professor Martin Carlsen together with Associate Professor Morgan Konnestad. I wish to express my sincere gratitude to them, because without their continous support and encouragement I wouldn't have come this far.

As my main supervisor, Professor Frank Reichert unreservedly shared his long term experience as a researcher, an educator and a leader. Despite having so many engagements as a dean, he managed to find time for me whenever needed and provided invaluable suggestions, comments and directions to keep me on the right track. Professor Frank has not only been a research supervisor but also a great friend who always cared for my family, from the moment he picked us up from the airport at our first arrival in Norway. I am so grateful to Associate Professor Martin Carlsen for his constructive feedback on all my writings, especially his sincere reviews with emphasis on pedagogical aspects of my research work. Thank you Associate Professor Morgan for your guidance and help with developing the mobile tablet technology based peer-assessment solutions. The extensive cooperation, continued support and ecouragement from all my supervisors were beyond expectations and I am ever grateful for that.

My sincere gratitude goes to Professor Andreas Prinz and Professor Frank Yong Li for advising on several research issues. Herein, I would also like to thank As-

# Summary

Higher education is facing unprecedented challenges with an increasing demand for high quality education, driven by tougher global competition. Student numbers are fast growing at most universities, whereas the sources of funding are not proportionally increasing. Subsequently, the teaching staff's workload gets higher and higher hence putting the quality standards at risk. As class sizes increase, it becomes more difficult to learn in a highly teacher-controlled environment, since the teacher cannot sufficiently address individual student's needs. Therefore, a teacher should be conceptually seen as a facilitator for students, who provides them with guidance and opportunities to explore and make sense of their subjects of study.

Sustainable quality education requires novel approaches to teaching and learning, to provide the best education with a minimum amount of resources. For instance, students should be encouraged to be more active in their learning rather than being passive receivers of the instruction. This study calls for a fundamental shift from instructionism (a teacher focussed educational practice) towards constructivism (a student focussed educational practice); keeping in mind that a combination of both practices may be needed in certain cases. In addition to adopting the appropriate educational praxis, innovations in educational technology can further enhance the learning experience.

Mobile media tablets are gaining popularity with university students as technology matures. Besides communication and digital media consumption as their primary functions, the latest mobile media tablets can also be used for data production and processing in teaching and learning contexts. This work revisits the practice of peer assessment as a means of formative assessment. Based on user centred design principles, engineering students at the University of Agder (Norway) and Kigali Institute of Science and Technology (Rwanda) were involved in developing a media tablet technology supported peer assessment system. The students' role in system development is reported as well as their active learning through peer assessment of mathematics assignments. Results of the experimental study generally showed improvements in the technical usability of the system throughout the development cycle.

Analysis of the pedagogical usability criteria suggests that there are possible learning gains of using such a system. The findings indicate that peer feedback has a potential to improve students' learning achievement and that media tablets hold a promising solution in learning mathematics and related subjects. Furthermore, the challenges of implementing effective peer assessment systems supported by new information and communication technology are discussed.

# Contents

# List of Figures

# List of Tables

# Abbreviations

| | |
|---|---|
| A-PASS | Agder peer assessment system |
| CAL | Computer aided learning |
| CW | Cognitive walkthrough |
| GUI | Graphical user interface |
| HTML | Hypertext markup language |
| ICT | Information and communication technology |
| ISO | International organization for standardization |
| KIST | Kigali Institute of Science and Technology |
| OHP | Overhead projector |
| OSI | Open Systems Interconnection |
| P2PASS | Peer-to-peer assessment |
| PC | Personal computer |
| PDF | Portable document file |
| RWTH | Rheinisch-Westfaelische Technische Hochschule |
| SD | Standard deviation |
| TPACK | Technology, pedagogy and content knowledge |
| TRL | Technology readiness level |
| UCD | User centred design |
| UI | User interface |
| UiA | Universitetet i Agder |
| WWW | World Wide Web |

# Part I

# Chapter 1

# Introduction

## 1.1 Motivation

A little while ago, in December 2011, while visiting a rural secondary school in Rwanda, I learnt that on average a typical classroom houses 90 students with a single teacher for any given subject. On the same trip, I also attended a Mathematics lecture session at the Kigali Institute of Science and Technology, where the lecturer was teaching about 150 students. In both cases, the teaching was characterised by the use of textbooks, basic blackboard and chalk as the only tools to support the teacher. The existence of largely crowded classrooms is not only a common sight in developing countries, but the situation is not much different in some developed countries, even though more technology is utilized in the latter ones. For example, more than 400 students registered for a mathematics course that was run at University of Agder, Norway, in the autumn semester, 2011. What was different here was that a live video stream was available for students who can not find a seat in the lecture hall. In all the three cases mentioned above, there was a common challenge in terms of how much assistance a teacher could provide to each individual student given the class size.

The last three decades have seen the world moving towards a knowledge economy, where knowledge is considered as a product or asset that can produce value. As a consequence, people of all walks of life are thriving to acquire more knowledge, a fact that has triggered a tremendous increase in number of students worldwide. University of Agder and Norwegian universities in general are a testimony to this phenomenon, with a steady increase of students' enrolment for the last five years as shown in Figure 1.1. Given the current trend, it is not surprising that there are predictions of worldwide number of students doubling by the year 2025 [3] compared to current situation.
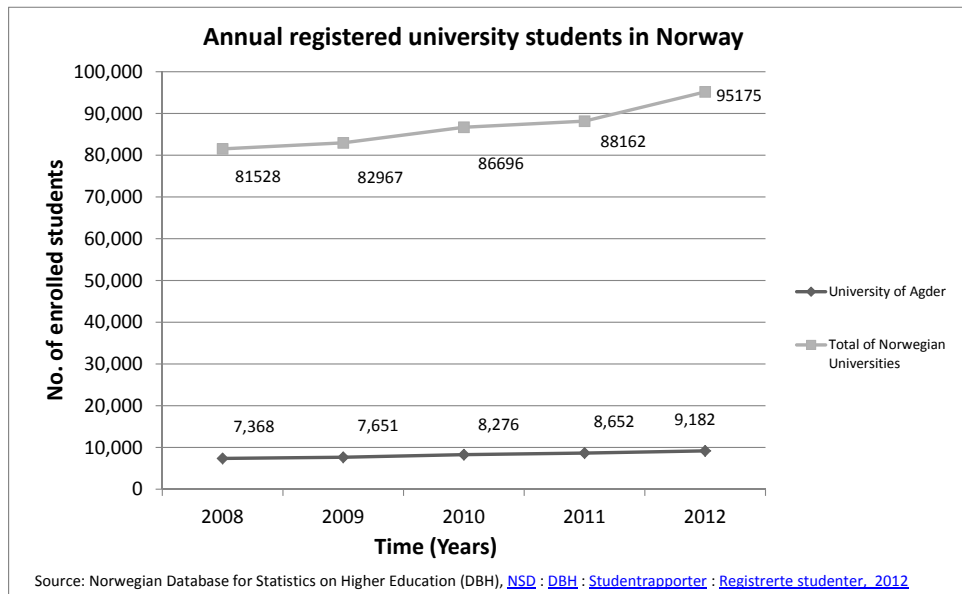
Figure 1.1: Annual registered university students in Norway

Further on, it is not only the number of students which is rising, but also the cost of education per student is getting worryingly high. Figure 1.2 shows a three-fold increase over a period of 20 years in the United States of America, an average from public, private not-for-profit and for-profit 4-years undergraduate degree granting institutions. Recent statistics from the American institutions of higher learning indicate that "between 2000 –01 and 2010 –11, prices for undergraduate tuition, room, and board at public institutions rose by 42 %, and prices at private not-for-profit institutions rose by 31 %, after adjustment for inflation" [4].

In addition to the general increase of the number of students as well as the cost of education, institutions of higher learning are also challenged by students' departures either as dropouts or transfers to other institutions. A study conducted in Norway in 2005 [5] found out that more than 50 % of all students leave their initial institution before graduation, including 17 % who never graduate with a degree. Even more alarmingly, in October 2012, The Telegraph newspaper in the United Kingdom, published from official data, that a record number of students left university courses in 2011, with a 13 % increase in one year [6]. The article goes on to indicate that 21.6 % of all university students are not likely to graduate at all, with just 48.6% expected to complete the degree course (in some cases). One of the possible reasons for the students to dropout and fail to complete their studies is the insufficient institutional support and the lack of alternative measures to address the negative effects of large class sizes [7], [8], [9]. Given the high costs of hiring teaching staff and the increasing number of students, universities and colleges can
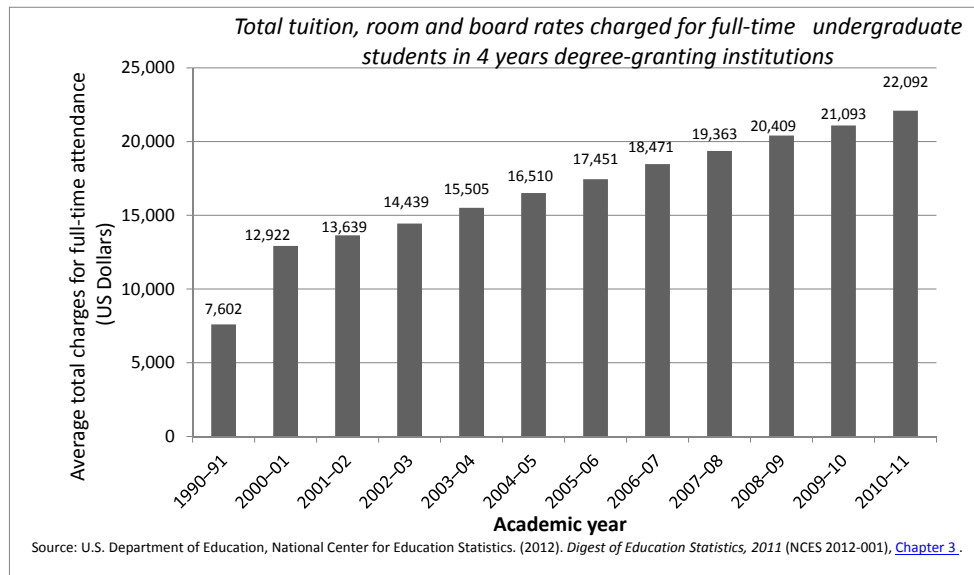
Figure 1.2: Cost of undergraduate education in USA

not afford to provide the same level of student support by using traditional teaching and learning methods only. Traditionally, the teacher was considered the main source of knowledge, whereby the students expected to learn from his/her instruction in a pretty much passive way. A typical traditional lecture is a live, face-to-face lecture taking place in a physical classroom or lecture hall, where one person (the teacher) speaks most of the time with little or no interventions from the students.

To cope with the increasingly complex and demanding work environments, educational systems need to make significant improvements in the way the knowledge is produced and transmitted or transferred among/between the people. The revolution of education requires a combination of efforts to understand the processes of human learning and innovations in learning technology. The students' learning should be facilitated in the best possible way without increasing the workload for the teaching staff. Engaging students in knowledge construction process and provision of frequent high quality feedback on learning achievement, has the potential to address the above raised issues. This approach however, comes with various challenges of its own, especially with practical implementation in particular subjects, such as the mathematics.

Mathematical subjects are taught at different levels of undergraduate studies and are a prerequisite for all engineering students. Usually, students from different engineering specialties are offered to take mathematics classes together, which may result in even larger classes compared to other subjects.

Learning mathematics often requires doing regular exercises, with access to

feedback on the achievement or learning progress. A step by step detailed feedback is one of the key elements to a successful learning of mathematics, given that an error can be committed at any given step of the answer, making the final answer wrong. A provider of this kind of feedback needs to carefully read through the mathematical expressions, with a possibility to indicate any mistakes/errors at the exact location on the worksheet. The process of distributing the exercises, collecting the answersheets, marking them and providing the feedback on paper for every student can be very time consuming and quite infeasible for one teacher with hundreds of students. Despite the teachers' good intentions, the task is too huge to accomplish for larger classes.

The provision of frequent feedback to hundreds of students can be effectively achieved if the students take part in feedback provision, whereby the whole process is facilitated by the use of appropriate Information and Communication Technology (ICT) tools. In this context, the students play a very important role in their successful learning as they serve not only as the recipients of knowledge, but they also participate, and collaborate to construct knowledge. It is important to understand how this can be achieved, considering the differences in the students' abilities, learning styles, and the complexity of mathematics as a subject. Several studies [10] [11] have reported positive effects of the peer assessment, a process through which a group of people such as students can rate each other and provide feedback (peer feedback).

It is noted that the subject of interest being mathematics, there is a need to find a technological solution that can handle the writing of mathematical expressions in a natural way and with the least efforts. Even though several studies praise the benefits of automated assessment and feedback [12] [13] [14], there are issues related to typing answers and the lack of possibilities to present answers in alternative ways, such as using diagrams (graphically) or different methods for constructed responses rather than multiple choice responses [15]. Chaoui [16] suggests that constructed response tests can evaluate higher order thinking whereas the multiple choice tests assess simple factual recognition. Taking into consideration those key points, this study aims to find out how to better provide a peer feedback in the context of mathematics education with large classes at university. Computer technology supported solutions can potentially come in handy while dealing with large classes. The research conducted intends to determine if technology based solutions would be accepted by the students[17][18]. It is indeed desirable to work with university students from different countries, in order to appreciate the impact of social-cultural influences on the solutions' acceptance[19][20][21]. Two studies

are eventually conducted in Norway and Rwanda, with the involvement of teachers and students from an institution of higher learning in each country.

Currently, the majority of students in universities and colleges are digital natives, who use various electronic equipments in their daily lives. Recently, media tablets like the iPad[1] are gaining popularity among the students. Besides communications and digital media consumption, as their primary functions, the latest media tablets are also being used for data production and processing in teaching and learning contexts. With regards to this, it shall be studied how to use them for feedback provisioning in mathematics learning. Media tablets, which are mobile devices, can be part of the solution as they support the electronic generation and distribution of feedback. Their touch sensitive screens can be used to naturally write mathematical expressions and make comments at any desired step of the answer. It is equally important to investigate the students' behaviour as they use media tablets and applications for feedback provision. This consists of the students' expectations, their attitudes and ability of use as well as the pedagogical utility of the student feedback provision process.

## 1.2 Research questions

The evolution of the art of teaching spans more than two millennia. Tremendous research efforts were initially directed towards the improvements of teaching theory and praxis, only recently the focus has shifted towards the learning process. The introduction of computer aided learning (CAL) in the early 70's, brought about a lot of changes, with new approaches to teaching and learning; including the active learning, student-centred learning [22], virtual learning [23][24] and ubiquitous learning [25] just to name a few. Although these latest developments have enormously contributed to the way people acquire knowledge today, many challenges still need to be addressed in order to provide answers to many open questions in teaching and learning praxis.

This research work aims to contribute to the understanding of how students learn in a community mediated by technology. It will explore the learning of mathematics through regular assessments and feedback provided by students (for other students), in what is referred to as peer-to-peer assessment (P2PASS) process hereafter. This approach heavily relies on technology solutions and derives from an analogy with the peer-to-peer computer networks, where each computer works as a server (source) and a client (sink) for others. The study also investigates the students' at-

---

[1]http://www.apple.com/ipad/

titudes towards using the technology tools. Students are involved throughout the study as it strives to answer key questions under the following four themes:

1. *Concept*: How to use peer-to-peer assessment in mathematics education?

2. *User aspects* (Acceptance, usability, motivation and engagement): What are students' attitudes towards media technology supported P2PASS in mathematics education at the university level? Can peer-to-peer assessment motivate and engage students more into studying mathematics?

3. *Technology aspects*: Is a media tablet supported P2PASS solution feasible and manageable?

4. *Teacher and organization aspects*: Would teachers and the university as an organization embrace a media tablet supported P2PASS solution? What are the challenges for implementing such a solution?

## 1.3   Research methodology

This research work addresses issues related to how people acquire knowledge, how they interact with technology enhanced learning environments, and seeks to develop usable technology solutions that are suitable for constructing and acquiring mathematical knowledge. Students and teachers are seen as the primary users of such solutions, hence their opinions can have a considerable impact either positively or negatively on any proposed solution. We have worked with university students and teachers from early concept development, and they were progressively involved in the design process. The ultimate goal is to make a solution which can meet the users' requirements and to increase the chances of the solution's acceptance.

The question of which research methodology to adopt is very crucial for any research work, because the methodology is linked to the research questions that can be addressed within the boundaries of the particular research expectations. The methodology puts limits on the answers that can be provided. For example, there is a possibility to use a paper based solution to explore mathematics education through P2PASS process. However, a paper-based solution can not allow the study to obtain valuable results of our interest. For instance, we need a digital solution to save time and reduce the administrative efforts required for handling a considerably large number of students.

Since our field of study combines research into education and human computer interaction, we need to combine the methods that are used in both worlds.

Both quantitative and qualitative methods are being used in educational research, where the former involves data collection techniques such as surveys and experiments whereas the latter typically employs interviews and observations for data collection. Besides the methods, the orientation of the research, also known as the *approach*, is equally important because the same observations can be described and interpreted differently depending on the way in which the method is used. Twining [26, p.153] suggests that "the approach employed also has implications for the uses that can legitimately be made of research outcomes". He argues that the empiricist approach may lead to making generalisations based on the research outcomes although the interpretivist approach might not even make generalisation a goal. A research methodology to be employed is chosen depending on the purpose of the research. The empiricists believe that the knowledge is derived from the sensory experience, and we support the view that the scientific knowledge is based on facts that can be observed through experimentation [27]. It is worthy noting that experiments must be conducted with caution in order to validate the findings. It is indeed necessary to eliminate all but the hypothetical causes of the event(s) under investigation, if the results are to be ascertained with confidence. It is in this regard that all of the experiments in this study have been carried out in controlled environments.

In addition to educational research, another important facet of this work is the usability testing. Despite having some similarities in the methods used, the goal of the usability testing is rather different. The goal of usability testing is to find design flaws in order to address the usability problems at various stages of the development cycle. On the other hand, the goal of the experimental research in education is to validate new assertions as well as the existing theories of interest.

As a methodology, I have chosen prototyping of a media tablet based solution to figure out whether the technology is mature enough to be used and also to understand additional issues, such as how to integrate technology in future teaching and learning, how to follow up students' progress on an individual basis and how to automatically derive usage data/statistics. By using prototyping methodology, we were able to design, test and implement a model of a P2PASS system within the time frame of the study. Given the study's limitations on time and resources, I have considered to first use off-the shelf iOS[2] based mobile applications, and then proceed with designing a new mobile web application based on feedback from the student test users. Following the principles of *user centred design* [28][29], the investigations in this study were undertaken as an iterative process, where the users provide data upon the receipt of which the designer/investigator makes necessary

---

[2]http://www.apple.com/ios/

improvements.

Several smaller tests were undertaken because they are likely to generate more
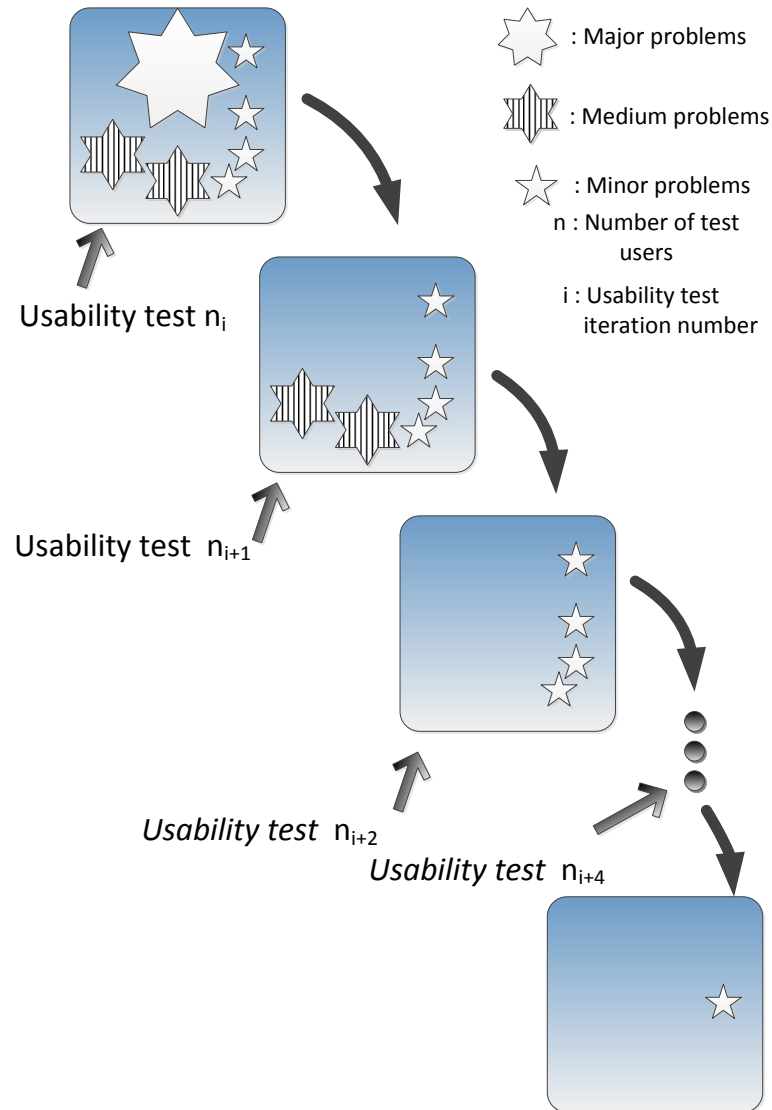


Figure 1.3: Iterative usability testing

feedback than a few extensive tests which are usually more expensive in terms of the invested time and money. Small user samples allow to immediately identify bigger issues of the solution, which are eventually addressed leaving room to the smaller ones and making the development process much faster. Figure 1.3 illustrates an iterative design process which consists of multiple usability tests involving a small number of test users. At least three design iterations are recommended with up to 10 test users [30]. In this study, we carried out usability testing in multiple steps,

starting with low fidelity (paper mockup) and medium fidelity testing of initial user interface designs. Iterative low fidelity testing was done at a very early stage in our design, as Krug [31, p.134] suggests that "testing one user early in the project is better than testing 50 near the end". Later on, multiple high fidelity tests were carried out on a working prototype.

The following subsections present in details the methods we used for participants' recruitment, data collection and analysis as well.

### 1.3.1 Recruitment of research participants

The sampling method chosen for this work was dictated by the need to select participants from groups of students who study mathematics at university level. This sampling technique, referred to as *Purposive sampling* [32], consists of selecting participants based on specific characteristics. The main reason for choosing the purposive sampling as a technique, is to ensure that the study involves a sample population which can enable the researcher to answer the research questions with a relatively small sample size. Our study involved exploratory research during the early stages of research, with the aim of finding out whether the idea of peer-assessment in learning of mathematics using media tablets is worthy investigating or not. At the middle and later stages, the study also intended to develop a pedagogically and technically usable tablet technology supported peer-assessment system for mathematics learning. Therefore, there was a need to undertake usability testing of the system, involving the most appropriate groups of users. To ensure a representative sample of users, this study first defined the target population's characteristics and then proceeded to recruitment. A typical user should be undertaking a university level mathematics course, with at least one year of university education. This was to make sure that the potential users have an experience of learning mathematics at the university and they are still taking at least one mathematics subject at the moment of investigation, a current student in other words. We know about the learning history of such students, their marks in previous mathematics exams, and they are likely to provide a much needed useful feedback because of their experience.

In this study, we have chosen the sample users among undergraduate engineering students, because mathematics is one of their compulsory subjects. For the recruitment, we have used three methods to invite them as our study participants: (a) Invitation by sending e-mails to students; (b) Invitation by actively approaching the students and offer them to voluntarily participate and (c) Invitation messages posted to the students' pages on the Learning Management System (LMS) as well

as large video screens on campus. One of the major features of purposive sampling, is the ability to hand-pick participants in order to balance the group sizes and/or meet certain important characteristics such as the gender and students' performance levels. The researcher organised the sample participants into groups with a goal of meeting the desired traits as far as it is possible (for example there was a limited number of female participants, which is typical of engineering courses, hence it was not possible to have a female member in every group). In an effort to minimize the subjectivity of the researcher (personal bias) and inconsistency of classification (which usually come with the purposive sampling technique), some of the participants were selected on a first come, first serve, as they replied to the invitation. It is also noted that in one experimental setup, all participants took part in the experiment as an alternative to a compulsory assignment: this allowed the study to collect data from those users who would not be otherwise interested in taking part.

## 1.3.2   Data collection

### 1.3.2.1   Interviews

Interviews are considered as a good data collection technique in both education and human computer interaction research [33] [34]. Interviews are mainly used because they allow the participants to extensively express their opinions about a topic of interest. Interviews allow to pose important open ended questions, on which the interviewees can answer in details and also ask for more clarifications from the interviewer if need be. The beauty of interviews is that they give room for not only broad but also deep coverage of the topic under study. In this study, I have conducted in-depth one-to-one interviews, with small samples of five to 10 users. Previous studies have shown that small user samples provide enough information [35][36], that is necessary for an iterative design process. Interviews are important to understand the users, their thoughts, motivation and challenges of the application under study.

Depending on the purpose, interviews can take different forms, from free-form unstructured interview, to semi-structured interview and structured interview. We have used interviews from initial exploration, where the participants were basically required to help us understand the needs and potential challenges of devising a solution for students to better learn mathematics. At the initial stage, interviews covered a broad range of issues related to learning mathematics and the possibilities of using mobile technology to improve the learning. Subsequent to understanding the needs

and expectations of the students, more interviews were employed in requirements specification, prototyping and evaluation of the design solutions. Jonathan et al.[34] indicate that interviews allow the researcher to develop further an interesting idea "on the fly", with a possibility to rearrange the questions or add new inquiries to increase the understanding. These authors however, advocate to use caution while planning and undertaking interviews.

There are risks of getting involved into unbounded discussions if the interview is too open, i.e. the open-ended questions are vague and lack limits of the permissible extent of the answers. While conducting the interviews in this study, I took notes and did observe the interviewee's reactions and attitudes. Additionally, video and audio recordings were carried out using the microphone and webcamera on the Laptop Personal Computer (PC). Effectively, the video and audio recordings are important for future documentation and easier recall of key points. Using notes and the recordings, I have classified (coded) the main ideas from the interviews into categories in order to separate important and useful answers from the less important ones. Further on, the obtained data could be easily interpreted and graphically presented.

Even though it is reported that it can be time consuming to process raw notes and audio recording from interviews [37], interviews are useful in user centred design because the sample size can be limited without affecting the outcome. Nielsen [38] advises to work with as few as five users to "find almost as many usability problems as you'd find using many more test participants". Interviews were used in this study to get the initial feelings of the users, on how they would react on the peer feedback as well as their perceptions on the new proposed solution.

### 1.3.2.2 Survey tools

Web-based surveys have attracted the attention of many researchers because they are low cost, accessible by many respondents in different geographical areas and they can be used to generate relatively complex graphical representations of results [39] in a short time. Web surveys are good tools for automatically generating statistical analysis. Studies on paper (print)surveys versus web-based surveys [40] [41] found no significant differences in the results obtained using the two methods. However, even though the web-based surveys are much better in terms of minimizing the administrative work, they suffer from lower response rates. In this study, the response rates were high because it was natural to use web-based survey as the students were already using a web based P2PASS solution on iPad tablets.

In a study on the factors affecting the response rates of the web survey, Fan et. al. [42] found that low response rates are caused by the problems in survey design, delivery methods (sampling, invitation designs, incentives etc.) as well as the technical failures. The authors suggest to use better survey formats in developing a survey and to apply a sampling technique which is relevant to the research context to ensure that the respondents can easily access the web survey and effectively submit their answers. Effective communication is also key to higher response rates, because the non-responding participants can eventually provide their answers if they get regular reminders. Our study participants were actively reminded to respond to the survey as I could physically meet them on campus.

The Google Docs Forms[3] were used to design, distribute and answer online survey questionnaires that we used in this study. The survey tool was complementary to the semi-structured interviews that were used in usability studies. Four types of questions were asked: (a) YES/NO type of questions, (b) 1 to 5 Likert scale attitude questions, (c) Multiple choice questions and (d) Open-ended questions. The online survey tool is very efficient in distributing questionnaires via Internet, answering questions and analysing results. After each usability testing session, a hyperlink was given to participants for accessing the survey form, so that they can answer the survey while they vividly remember the events of the experiment. On the other hand however, participants were also able to send in the answers at their convenient time, provided that they have Internet access.

### 1.3.2.3   Researcher's observations

Data collection in a lab setting involves observing the users, to find how they behave as they interact with the system under study. Observation techniques have been used in the human computer interaction context not only as *controlled observations* in laboratory, but also as *naturalistic observations* when the observations take place in a natural, normal context of use. The researcher's observations are of a great interest because so often what the users do, in reality, as they undertake a given task may differ from what they say they would do [43]. During the observation, the observer tries not to interrupt the users or distract them to ensure that the users perform the given tasks as they would in the absence of the observer. Users tend also to ask for assistance from the observer/researcher on how to use the system or the devices, but the observer must avoid that. Love [44] advised three main techniques used for data collection while observing:

---

[3]http://www.google.com/google-d-s/forms/

- Audio recording: the researcher records his own observations verbally as the users perform their tasks. The observer must avoid distracting the users by attracting their attention to himself as he talks or walk around the testing lab.

- Video recording: video provides a great deal of information on how the users' react during the usability testing. It captures the users' actions as they try to perform the given task. The major drawback of using video lies in the possibility to obstruct the users as the researcher try to capture the actions on the user interface. All precautions must be taken to minimize the observer activity.

- Coding form: the observer writes down what he/she is seeing happening during the experiment. It can be quite demanding though, because the observer has to observe every step of the task and write down the users' behaviour at the same time. A screen capture would be better, but in this particular case it was not possible to do so because of the limitations on the iPad.

During the usability testing in this work, users were required to undertake the *Think Aloud* kind of tests while the researcher also recorded users' actions on the media tablets. In thinking-aloud, users verbalize their thoughts so that the observer can have a perception of what they think as they interact with the system under test [45]. It helps the observer to understand how users view the system, and also their feelings towards the system. It is important to be aware of the fact that even when users verbalise their thinking, the verbalisation is still a product of the users and what they allow for the researcher to hear. The video recordings of the user interfaces captured all the users' activities coupled with their verbal expression; which are good sources of qualitative data. It is noted that the tests were not carried in designated usability laboratories; therefore the observer's presence might have an impact on the users' performances as they were in the same room as the observer.

Prototyping in this study, focused on fast development of a running P2PASS solution in the context of a PhD research project, with limitations on time and resources. I was the only observer (PhD candidate) for all usability testing sessions. In addition to notes taking, I also used a video camera recorder throughout the sessions for future reference. After the testing sessions, I was watching the videos to extract valuable information that I would otherwise have missed. Besides the limitations on the researcher's time, the availability of test users was another challenge. Since the solution is meant for formative assessment purposes, I had to plan the test sessions according to the teaching schedule and the mathematics study units.

### 1.3.3   Data analysis and interpretation

The nature of this research work is grounded into the philosophical enquiry, which questions the nature of reality, the nature of knowledge (how do we know things) and the nature of value. It combines the ontology (what is real, the worldview), the epistemology (how do we know or a way of knowing) and the axiology(what is of value, how we decide on what is important) [46]. Questioning of the various aspects generated a lot of data in this study. I collected data through interviews, surveys and observations as well. After data collection, I proceeded with data analysis as an attempt to summarize the data, so that it can be interpreted to find meaning. The audio and video recordings were transcribed verbatim and data classified in relevant categories for in-depth interpretation. Effectively data was saved into spreadsheet files to facilitate the analysis and interpretation. The data typically contains descriptions of attitudes and opinions of the study participants, which allow to portray what are their realities, what they believe doing and why they would do it in a given way. My goal in conducting a qualitative interpretation is to develop an understanding of the students' behaviour in a particular learning context, which involves learning of mathematics using media tablet technology. Furthermore, by data interpretation, I attempt to make sense of any new information that emerges from the study and new ideas thereof.

This kind of analysis and interpretation has a subjective aspect, hence it does not necessarily guarantee the generalization of the findings of this work to other scenarios; considering the uniqueness of the settings and participants [47]. The narrative descriptions given in this work, are often derived from or complementary to the visual data displays such as the pie charts, histograms, other graphs and tables.

## 1.4   Ethical considerations

This study involves humans as test subjects. They were given all the necessary information about the goals of the study and the test trials. The users were informed that the study is about future education and I explained to them all techniques that will be used during the study. Subsequently, all participants offered an informed consent to participate in the study and where necessary to take their images/videos and audio recording. The data collected during this study is being used and stored according to the Norwegian standards regarding privacy and data protection. All data

collections were reported to the Norwegian Social Sciences Data Services (Norsk samfunnsvitenskapelig datatjeneste AS). It is confirmed that no human beings or animals were harmed or abused in any other form. Dummy names are used in the reports to preserve the anonymity of the participants; and where it is not possible (reports with pictures), the users have given consent for the publication.

## 1.5    Structure of the thesis

This thesis is organized as a compilation of scientific papers. It is comprised of two main parts, with Part I being an overview of the research work, consisting of the concepts on which the research papers are written as well as a summary of contributions and concluding remarks. The papers addressing related topics are discussed together in a chapter. Part II presents six research papers in a chronological order of publication.

The structure of this dissertation is as follows:

The next section, Chapter II discusses the concept of student centred learning, which is relevant to two scientific papers. The chapter explains the importance of the practice of student centred learning and provides an overview of how this fits in future concepts for teaching and learning at the university level. The chapter presents topics addressed in Paper 2 and Paper 4.

In Chapter III, an approach to collaborative learning through peer-to-peer assessment process is discussed. The theory behind the process is explained, with reference to studies published in Papers 1, 3 and 5. The following section in Chapter IV, describes a user centred design approach for developing a mobile tablet based solution to support the peer-to-peer assessment process. The design approach is discussed in detail, with insights on the pedagogical and technical usability of the sytem. A detailed overview of the challenges of developing such a system is given alongwith the potential benefits of deploying such a system to enhance the learning of mathematics. Paper 6 elaborates on the content of this chapter. Finally, the last section of Part I, which is Chapter V, contains a summary of the major contributions of this research work with concluding remarks on future research directions. As mentioned above, Part II of this dissertation consists of scientific research papers published during the course of this study.

# Chapter 2

# Technology supported student centred learning

## 2.1 Introduction

The challenges of traditional brick and mortar classrooms are still a common sight in universities, despite the advancement in educational technology over the last 3 decades [48]. Martin W. Gerdes, an experienced research fellow at UiA, graduated from the "Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH)" Aachen University (Germany) in the mid 90's. He recalls how he and fellow students were told beforehand that 50 % of them were likely not to graduate in the end. Of his most vivid memories are mathematics lectures with more than 1000 students. The class setting was such that the lecturer would talk through a microphone while scripting notes on the overhead projector (OHP), with just a few glances at the audience from time to time. Martin claims that in such a learning scenario, a limited number of students could really follow the teaching, while the rest would simply be involved in note taking or other activities. The teaching was so impersonal, and there was a very limited interaction between the lecturer and the students. Furthermore, during the first introductory class, students were told that, in their professional life, they will not need more than 5% of what they are taught at university.

Martin notes that it was not clear to the students why they would have to learn all the content, if not to teach them how to learn new things rather than learning the content per se as he suggests. He reckons that the "5%" statement was so demotivating and could possibly lead to the "50%" failure rate. It's important to make the students aware of the learning goals early on, so that they can spend their efforts towards reaching those goals [49]. Jiang et. al. [50] reported that specific learn-

ing goals are necessary to produce substantial performance improvements whereas vague or non-specific goals might not have impact on the performance.

A lot has improved since Martin's undergraduate studies, and even more changes are anticipated for learning in the future. Using indicative teaching and learning scenarios at UiA, this chapter presents a framework for future university teaching and learning, followed by a contribution towards enabling the student centred learning through technology.

## 2.2   Future university teaching and learning

Today's university teaching environments are evolving, embracing new methods of teaching, and embedding various forms of technology in education. Many universities are equipped with modern computing infrastructure, including a Learning Management System (LMS). LMS are expected to have great positive effects on university teaching and learning, both on campus and off-campus [51][52][53]. Even though LMS can help teachers and students in communicating, content sharing and assessment, more research efforts are necessary to increase their effectiveness [54] and their role in supporting teaching and learning.

Ragnar Johnsen, an associate professor at the University of Agder, shared with me his experience with second and third year students in Electronics Engineering and Computer Science as they approached the semester examination day (autumn, 2012). In a class of 110 students to sit for exam in Data Communications subject (DAT204), forty to fifty students (i.e. between 36.4% and 46%) sought a face-to-face contact with him just within the last two days before the exam. He mentioned that students were seeking help to answer questions from previous years' exams, even though they were made available to students through the LMS at the start of the semester. Despite the professor's efforts to help students during the semester teaching hours (lectures and laboratory time), there was still a high percentage of students that did not feel sure of their competence and learning achievement in this subject, and some who never tried to work on these recommended sample questions.

Ragnar's statement indicates that students are not engaged enough in learning. This issue can be addressed through development of new pedagogical practices, promoting the students' ownership of learning, students' responsibility, engagement and personalization of learning.

University education attracts large numbers of students with different capabilities and competencies. Furthermore, social-cultural backgrounds and geographi-

cal locations have a great impact on how students learn. There are also financial constraints which have negative impact on what universities can afford in terms of services offered to the students. A university should be able to enable all students achieve their learning goals, despite the diverse nature of students and the scarcity of resources.

Several educational institutions (including UiA) have embraced teaching and learning technologies to support the learning processes and related administrative tasks. Although technology integration into courses has a potential to improve learners' performance, the real benefits can only be achieved by adopting appropriate pedagogy for university education. Christensen et al. [55] argued that simply putting computers in classrooms cannot bring the much needed transformation towards a student centric learning, where the student comes first. In my opinion, developing technology for education should go hand in hand with revisiting the existing pedagogy. Traditionally, teaching and learning were commonly characterised by a teacher lecturing (by instruction in some cases) to the learner who will later on be assessed typically by how much he/she can remember of what was taught. There are several implications of this method, as the students are passive in the whole process.

Modern educational practice advocates for a change in the teacher's role, from that of a source of knowledge to the "facilitator" of the learner's activity [56]. Jonassen et al. [57] presented a number of students' activities which allowed them to think, construct knowledge and learn using technology within a constructivist perspective. According to the same authors, meaningful learning comprises of intentional learning, active learning, constructive learning, cooperative learning, and authentic learning. Meaningful learning can not be achieved only through technology in terms of hardware and software, both technology and classroom settings must be taken into account in new concepts of e-learning, mobile-learning, virtual classrooms [58][59] and interactive classrooms [60][61].

Recent developments in Internet and multimedia technologies have prompted the proliferation of electronically supported teaching and learning (e-learning). e-learning is especially popular in online and distance education programmes, with support for self-paced learning and cost-effectiveness among several other advantages [62][63]. In addition to e-learning applications accessible on laptop/desktop computers, handheld mobile devices are being used for educational purposes, in what is known as "mobile learning". Mobile learning or m-learning offers mobility, portability and availability of learning anytime, anywhere thus making "*ubiquitous learning*" [25][64] a reality. Ubiquitous learning is a model of learning which is not

constrained by time and space limits, a model that should allow just-in time access to learning content and supports interactions with content as well as other learning resources such as tutors and peers.
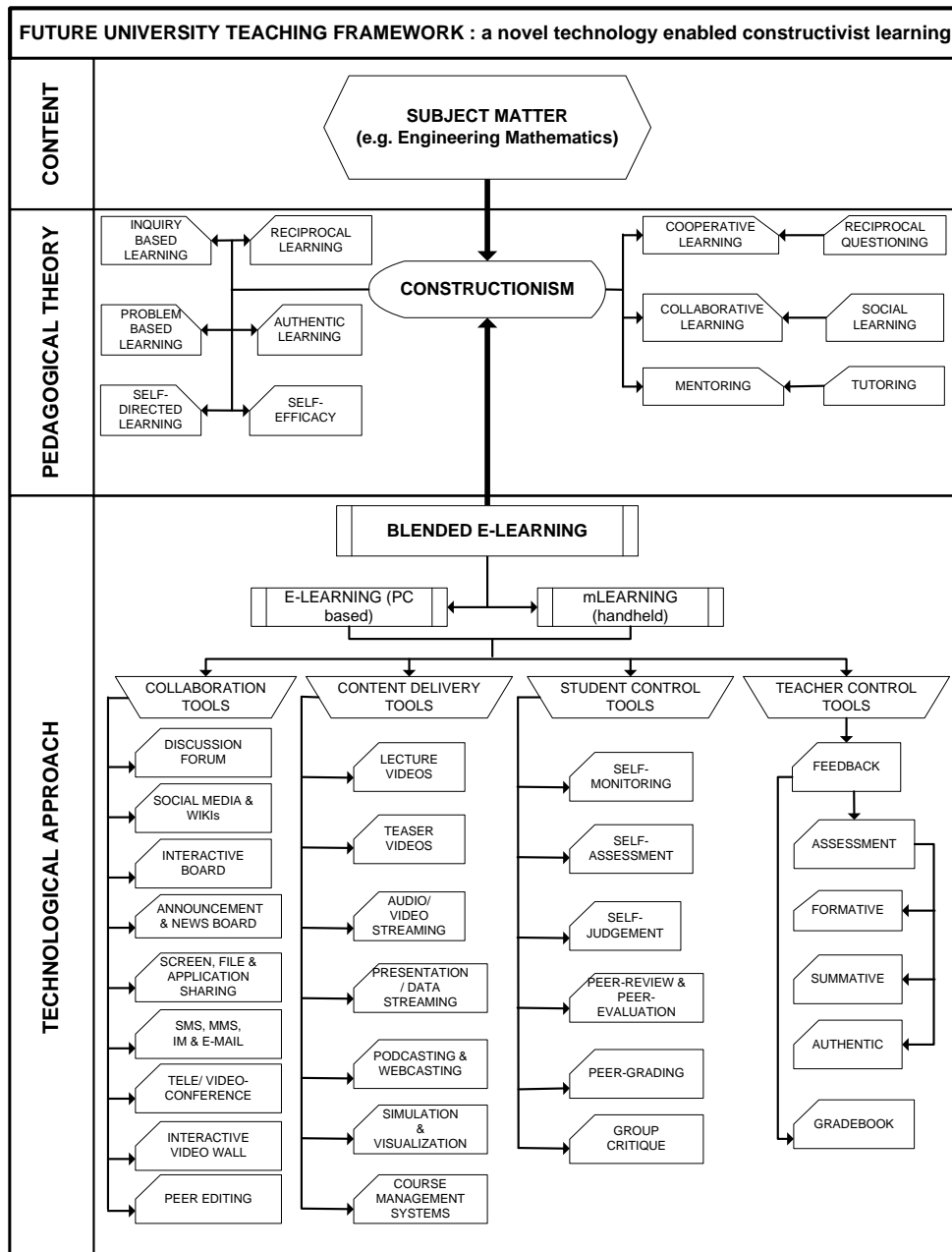


Figure 2.1: Future university teaching framework

Future universities will have to strike a balance between investing in technology development and streamlining the pedagogical theories to meet the requirements of learning in media rich environments. Koehler et al. [65, p.62] addressed the

"*complex, ill-structured task*" of teaching with technology. He proposed a basis for effective teaching as a combination of and interaction among three bodies of knowledge: the technology, pedagogy and content knowledge (TPACK). The complexity of teaching with technology is not only a concern for teachers, but also for learners (students). A teacher's understanding of content, methods of teaching and knowledge of technology would not necessarily lead to effective learning. Inspired by the TPACK concept, this thesis proposes a framework for future university teaching, presenting interconnections between the mathematical content, the pedagogy and technology, in the context of a student centred teaching and learning. The research work published in Appendix B (Paper I), depicts the main components of the framework, with constructivist epistemology [66] at the centre of the pedagogical theory. The main goal of the framework shown in Figure 2.1 is to present a new approach to technology enabled constructivist learning, promoting active, interactive and collaborative learning with the student at the centre of the teaching/learning process.

## 2.3 Enabling student centred learning using new media technology

Nowadays most Norwegian university students are in possession of handheld mobile devices. Devices are getting more affordable on one hand, but also their processing power and storage capacity are fast improving on the other hand. The majority of available devices can support multiple functions from audio and video calls to text chats, gaming, Internet browsing, media consumption and a multitude of other advanced applications. Considering the potential learning opportunities, universities are increasingly adopting m-learning [67][68][69] to supplement formal teaching and learning. M-learning is a hot research topic both in academia and industry as well due to the associated technological challenges such as access technology (bandwidth), usability of the user interfaces, memory capacity and battery life on one hand, but also pedagogical challenges on the other hand [70][71][72]. Mobile learning is still in its infancy and more research work is needed in devising pedagogy for mobile learning to enhance students' motivation, to make learning more personal and enhance students' responsibility as well as ownership of learning. Mobile learning is credited with the possibilities of enabling student centred learning, providing the conditions for students to learn anytime, anywhere and promoting self-motivation and self-regulation in learning [73].

Until the 1990's, going to a traditional university campus was the most com-

mon way of getting access to learning content either face-to-face contact with a teacher or reading paper based materials. One of the important goals of attending a university course was to be able to get the knowledge which would be otherwise inaccessible.

Nowadays, people are aware that they can have access to a lot of content using new media technology. There is in fact a broad range of learning materials which can be accessed through the World Wide Web, and there is much that students can choose from. Given the availability of multimedia learning materials and the differences in students' approach to learning, it is necessary to provide the students with a possibility to choose the most appropriate learning materials according to the characteristics of their situation, referred to as "context". Kumar[1] is a postgraduate student at UiA whom I consider to portray a typical student in study habits and approaches chosen for learning the course content. He said that he usually reads printouts of the learning material if he needs to concentrate and achieve deep learning; but this learning style costs him a lot of time. He said that he prefers to attend a lecture only when he needs to capture key points in short time. Additionally, Kumar also uses lecture videos but only for learning non-critical content. Typically, Kumar uses different learning materials as his context changes.
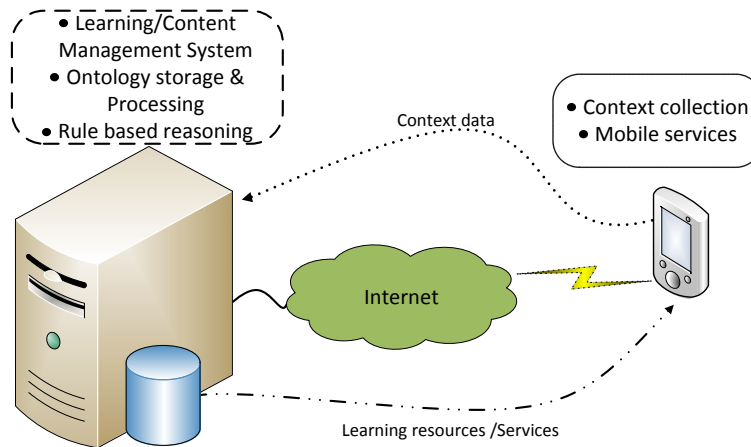
Figure 2.2: Student centred learning service architecture

Often students have different learning styles (the way they learn from experience [74]) and they use different ways to achieve the same learning goals. We suggest that students' should be encouraged to make their choices in learning, to meet their individual needs. In our work published in Appendix E (Paper IV), we present a technology solution which can help to support student centred learning.

---

[1]Not real name.

The paper proposes the use of semantic web technology to offer personalised services to students. Figure 2.2 shows a student centred learning service architecture which proposes to integrate a learning management system and semantic web technologies for supporting context aware mobile learning. The student is at the centre of learning since the learning resources are chosen based on the student's context which includes the student's learning style, course of study, instant activity and location. Kumar portrays the importance of the student's role in defining the learning goal and the ways to achieve it. By knowing personal learning goals, students can participate in personalizing the learning experience which suit them. Wisher [75, p.186] argued that "learner centered pedagogy addresses what students need to learn, what their learning preferences are, and what is meaningful to them". Because of the high amount of information at hand, context aware systems are very helpful in suggesting relevant content to students so that they can spend their time efficiently in learning.

## 2.4   Chapter summary and conclusion

Future learning will embrace new pedagogical models supported by technology. Teaching and learning in the future will require further integration of content knowledge, pedagogical knowledge and technological knowledge using a student centred learning perspective.

The framework outlined in this thesis work, brings out fundamental components of a constructivist approach to learning with interconnections to technology based tools. We argued that deploying technology is not enough to address the issues raised in this chapter, we also need to look at new pedagogy to effectively use the technology. Within the context of the framework discussed in Appendix B (Paper I), this chapter proposes a technology based content delivery tool to support a student centred learning environment. A student control component of the framework, the peer-review and peer-evaluation (assessment) in particular, will form the basis for the study discussed in the remainder of this thesis.

# Chapter 3

# Involving students in assessment for learning

## 3.1 Introduction

One of the salient features of learning is assessment. Assessment can serve different purposes including the measurement and reporting of the students' achievement at the end of a course or a teaching unit. Assessment can also help to identify the students' learning needs and competences during the course of learning as well as monitoring the students' metacognitive knowledge. This chapter discusses the assessment for learning, a form of assessment which provides opportunities for the students to learn. An overview of the assessment for learning is presented, followed by our proposal for doing such assessment in mathematics learning. A new approach to assessment for learning is suggested based on the results of our studies on mobile media tablet technology supported assessment in mathematics subjects.

## 3.2 Assessment for learning

Research into the practice of assessment stresses the importance of assessment for learning purposes, the assessment which focuses on fostering the students' learning. In a comprehensive literature review on assessment and classroom learning, Black et. al. [76] present the evidence that regular feedback on students' learning leads to considerable learning gains. The authors discuss a great deal of research efforts dedicated to the assessment for direction and motivation purposes, known as *formative assessment*.

Formative assessment consists of regular assessments which take place during the course of study. These assessments are designed to inform the students about their learning progress, and provide them an opportunity to address any potential shortages in meeting their learning goals. Although the teacher may be involved in formative assessment, students play a key role because they are the ones to decide on how to use the assessment's outcome, especially in case some shortcomings are found.

Provisioning of formative assessment requires clear guidelines for the students to be able to realise its benefits, given that students learn differently and do naturally have different motivations. It is suggested [76] that in order to avoid underachievement as a result of formative assessment, emphasis should be put on the learning goals instead of the performance goals. Learning goals aim at the student gaining a know-how whereas the performance goals simply aim at them completing successfully given task(s) regardless of whether they understand how to do it or not. Black et. al. [76] reported that the learning goal approach yields higher motivation and achievement compared to the performance goal.

The processes of formative assessment (the means) are eventually more important than the end results (the product) [77], because what is needed is to show the students where they fall short of expectations and how to meet the expected standards or goals. It is indeed important in formative assessment to emphasise on the type and quality of feedback given to the students. Formative assessment should motivate weaker students whilst encouraging the stronger ones to achieve even higher. It is reported that assessments with grades are likely to have negative effects [78]. One of the possible reasons is that students may focus on scoring higher grades rather than knowing the subject or unit of learning and being able to explain it to others.

## 3.3   Feedback for learning

The term *feedback* as used in control engineering means a signal or a value which is taken from the system output and sent back/ injected to the input of the system ( or process) in order to allow the system (or process) to generate a desired outcome. Likewise, if we make an analogy with the educational systems, a feedback is any information given to students to make them aware of the state of their achievement in learning, in order to enhance their learning so that they can reach a desired level of achievement [79]. Feedback for learning is a key component of formative assess-

ment, in a sense that the success or failure of such assessment depends considerably on how the feedback is provided and students' use of feedback [80].

Feedback can take different formats, including the feedback of grades only, feedback of grades with comments and feedback of comments only. Studies on feedback learning gains have shown that the feedback of comments only yields highest level of improvement. Then follows the feedback of grades with comments which leads to medium improvement. On the other hand, feedback of grades only has led to a decline in students' achievement [76].

Feedback provisioning for formative purposes requires interactions between students and the feedback provider. Through interactions, a common understanding of the assessment process is reached in order to negotiate the outcomes. This was confirmed by one of the student participants in this study who stated that "when you do the review, you have to really understand what you are working with". For the formative assessment to be effective [20], students should be convinced that they can succeed if they make use of the feedback they receive, otherwise low achievers are not likely to benefit from it.

Whether the students make use of feedback or not might depend on several things, including the timing of delivery and the mode of delivery among others. As we deal with mathematics learning in large classes environments, we understand that it would take a long time for the teacher to provide feedback to each and every student. It is important to provide feedback in time [81], as one of our study participants mentioned that "getting quick feedback felt good". Besides the issue of time spent on assessing many students, the mode of delivery (communicating the feedback) may also affect the usefulness of feedback. The next section describes how we propose the involvement of students in formative assessment and the use of tablet media technology, an approach to address the issues of timing and mode of delivery of formative assessment in mathematics education.

## 3.4   Students as assessors: Peer-Assessment

The involvement of students in the assessment for learning has many advantages as reported in several studies [10][82][83][84]. Studies suggest that when students are involved in their own assessment and the assessment of their peers, it can lead to deep learning, increase students' ability to reflect on learning, critical thinking and students' engagement. A student participant in our study at Kigali Institute of Science and Technology (KIST), confirmed the importance of peer-assessment in

relation to the development of her reflective skills, saying that during the assessment she could reflect on different methods of working, reasoning and providing answers. Stiggins and Chappuis [85] argue that students who spend their efforts to analyse quality work and criticise its key elements, are likely to achieve better performance. The authors claimed that "when students learn to apply these standards so thoroughly that they can confidently and competently evaluate their own and each other's work, they are well on the road to becoming better performers in their own right" [85, p.20].

Mathematics assessment has to take into consideration the characteristics of what is to be assessed in order to define how the assessment activities can be carried out. Niss [86] has indicated a set of traditional tasks (oriented activities) which are central to mathematics education: *questionnaires, exercises and problems*. Depending on the task, students may be asked questions about definitions, formulae, properties or results of computations. Additionally, students may be required to provide answers to exercises comprising of routine operations or solve problems which involve reasoning on strategies and multiple computational procedures. The variety of the mathematical questions is also expressed through the formulation of questions, varying from the straight, single answer (closed answer) category to the open-response type. For instance, questions can be formulated using the imperative expressions such as *define, state, calculate, find etc.*, with a possibility that there is one specific method which leads to the correct answer.

On the other hand, there are questions which require interpretation by the students in order to determine which methods and procedures to use for answering. For example "A ball of ice melts so that its radius decreases from 5 cm to 4.92 cm. By approximately how much does the volume of the ball decreases?" [87, p.267]. Assessing a response to such a question requires an appreciation of how the student identified the requirements that the answer should address (understanding the task at hand), selection and use of strategies and procedures as well as the presentation of the mathematical expressions in the answer. I am of the view that assessment criteria should be explained to the students to enable them to appraise all components of the answer. Additionally, earlier studies have noted issues with students' capability to assess their peers' work and related responsibility [88], because they are not experts in the field of study. Therefore, I suggest that a reference answer sheet be handed to students before they can carry out peer-assessment in order to improve the quality of the assessment.

## 3.5 Technology supported peer-assessment in university mathematics education

In this dissertation, I propose a solution which allows the students to assess each other's work, with consideration to the characteristics of mathematics as a subject. In our work presented in Paper III and Paper V (appendix D & appendix F in this dissertation), we study the possibilities of involving the students in their formative assessment. We discuss our approach of using mobile tablet technology to support peer assessment in mathematics, and we present the results of the studies carried out in two countries, Norway and Rwanda respectively. In both countries, we worked with students and mathematics teachers to organize peer assessment sessions concurrently with the instruction.

Using similar techniques at two institutions of higher learning, students carried out peer assessment in mathematics, while the researcher observed them working together and interacting with the media tablet based peer assessment system. Mathematical tasks at UiA consisted of Calculus exercises (functions, derivatives and integrals) whereas students at KIST answered questions on Fourier series.

Based on the peer-to-peer assessment processes that we developed, the above studies confirmed that there is a possibility to embed peer assessment into university mathematics education. The students are positive about the concept of peer-assessment in mathematics, with supporting arguments such as "I really like the idea of multiple feedbacks"; "easy to get a copy to evaluate. I did not have to get the written copy, since everything was in pdf on Fronter LMS"; "I realize that it is one of the best way to feel responsible in serious tasks"; "It helped me, because I am very happy to be corrected or to be advised by my classmate rather than by the teacher"; "I believe this is a great way of sharing knowledge and collective learning and reflection"; "It is helpful because I want to compare my level of course understanding with that of my peers".

Despite the difficulties due to using new media technology and dependency on the wireless network connectivity, students expressed the benefits of having a mobile tablet technology supported system, with one of them saying "it enabled us write using pens like we do on papers resolving maths problems". The facility to digitalize the students' work has several direct and related advantages, because "you can save your work for a long time", "the iPad is portable, that means wherever you are you can apply for peer assessment" and "multi-modality: that machine has many programs which can be used when you are doing your assessment". It is indeed helpful to be able to revise the learning material while answering or assess-

ing the given work; a fact that was observed on several occasions during the user studies (from time to time, students were browsing the web looking for mathematics notes).

By comparing the attitudes of the students at UiA and those at KIST shown in Figure 3.1, we can see that the students in Rwanda scored higher on the Likert scale. It is also observed that in KIST, the standard deviations (SD) are smaller for all the attitudes' measurements, which indicates that the sample students have more closely related attitudes towards the P2PASS. Cultural differences have influences on technology enhanced learning [89][90], which can impact on how the students in general interact with the computer mediated learning environments. Based on personal observations, I think, in Rwanda for example, people with education enjoy a much higher status in society. Improving ones' ICT skills and using ICT tools can help to achieve this much needed status. On the other hand however, in Norway, the majority of university students have access to latest ICT tools; hence using them does not contribute that much to their status in society. From this perspective, it is understandable why the students at KIST were more positive about the new technology supported pedagogy.

| Users' attitudes measurement parameters | Mean | | Mode | | SD | | Variance | |
|---|---|---|---|---|---|---|---|---|
| | KIST* | UiA** | KIST | UiA | KIST | UiA | KIST | UiA |
| Rating of peer-assessment on 1 to 5 Likert scale (5 - Strongly Like) | 4.74 | 3.46 | 5 | 3 | 0.45 | 0.88 | 0.20 | 0.81 |
| Difficulty to provide peer-feedback (5 - Very easy) | 3.65 | 3.17 | 3 | 4 | 0.71 | 1.05 | 0.51 | 1.15 |
| Difficulty to use the media tablet supported system (5 - Very easy) | 3.43 | 3.25 | 4 | 4 | 0.79 | 1.19 | 0.62 | 1.45 |
| Usefulness of peer-feedback (5 - Very useful) | 4.70 | 3.67 | 5 | 4 | 0.70 | 0.96 | 0.49 | 0.95 |

*KIST – Kigali institute of Science and Technology, RWANDA; **UiA – Universitetet i Agder, NORWAY.

Figure 3.1: Comparative table of users' attitudes in KIST and UiA.

The higher values of SD at UiA could be resulting from the fact that the students had varied experiences with technology supported learning, some of them already using media tablets and personal computers in learning, whereas all students at KIST had experience neither with the LMS nor with the media tablets. The Mode values in Figure 3.1 indicates that more students at KIST perceive P2PASS to be very useful as compared to those at UiA. The graphs in Figure 3.2 and Figure 3.3 also show some differences on the students' perceptions about student generated feedback. Students at KIST show a higher tendency to believe in the validity of the peer feedback, whereas at UiA there is a non-negligible number of students who are not sure about it.
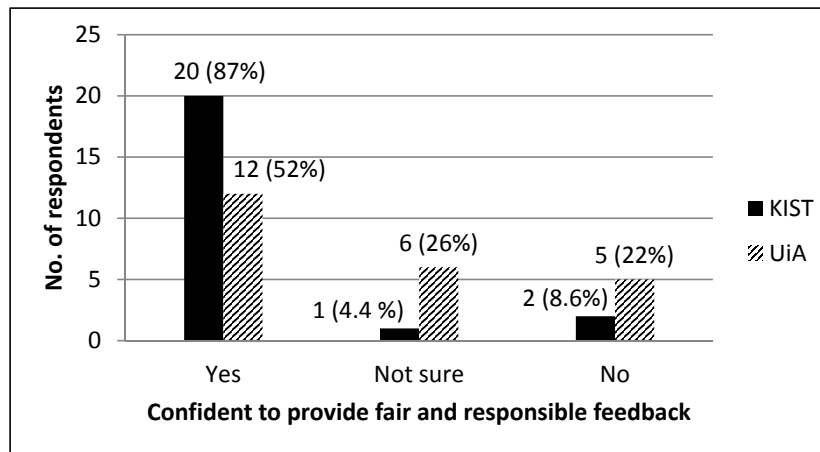
Figure 3.2: Students' confidence to provide fair and responsible feedback.
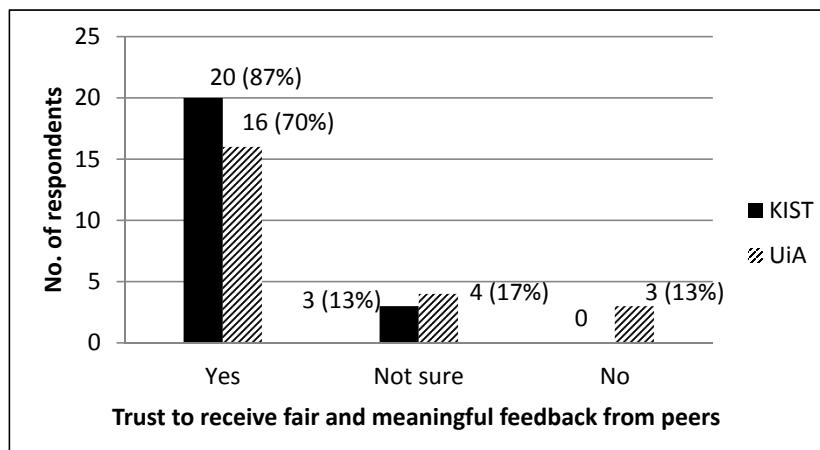


Figure 3.3: Students' trust to receive fair and meaningful feedback from peers.

Through discussions with students, there emerged new suggestions to embed peer-to-peer assessment into other technology enabled pedagogies, such as the reverse instruction [91], a technique also known as "flipping the classroom" or " inverting the classroom" [92]. The basic principle in inverting the classroom is that the learning materials are made available to the students outside the classroom, which allow them to explore and study the contents before meeting with the teacher. The assumption is that once the students have studied the material, the contact time with the teacher would be used for clarifying any difficult points and further interactions with the students. In our experiments, students suggested that they could take a self-study followed by a peer-to-peer assessment as shown in Figure 3.4. After the assessment, students would have a better idea on the achievement gap, so that they

can seek help from the teacher for them to meet their learning goal. Working with the teacher, they can improve on their achievement and then take a second round of peer-to-peer assessment.
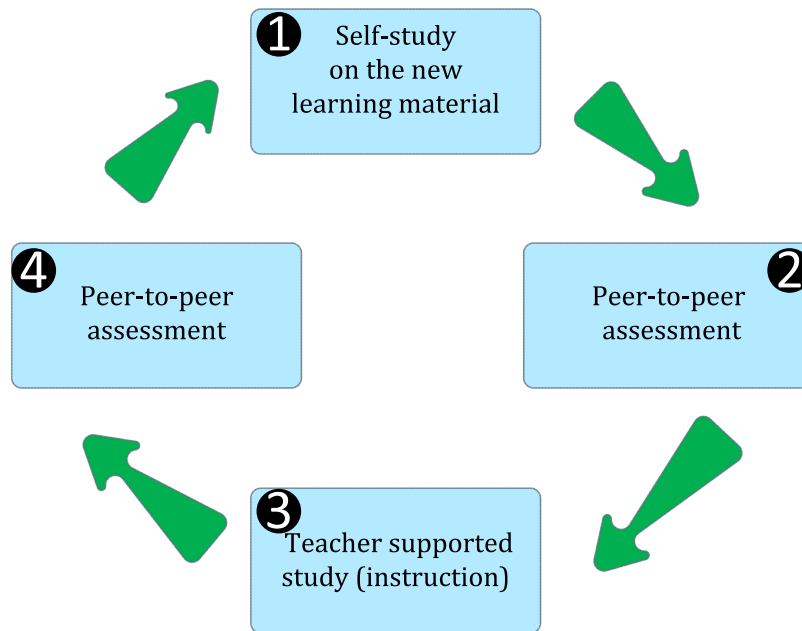


Figure 3.4: Inverting the classroom with peer-to-peer assessment

## 3.6   Chapter summary and conclusion

The purpose of this chapter was to provide insights into the practice of formative assessment, with the intention of devising and testing how this can be done in mathematics subjects. This part of the dissertation supports the concept of considering students for their own assessment for learning. The studies undertaken in this research work indicate the possibilities of using media tablet technology to support P2PASS process. As a result of the user studies carried out in two different countries, we found that students are likely to adopt the new form of formative assessment. The students expressed a willingness to adopt the technology, but they also pointed out a necessity for developing an integrated tool for improved technical and pedagogical usability.

# Chapter 4

# Developing a mobile tablet supported peer-to-peer assessment solution for mathematics

## 4.1 Introduction

The evolving world of technology offers new opportunities from the applications perspective. The teaching and learning field is no different to other areas where latest technical innovations can lead to great practical improvements. The affordances of mobile tablet technology have shown a potential to enhance learning of mathematics as I discussed in the third chapter of this thesis. However, since the concept of using mobile tablet technology for P2PASS in mathematics is new, challenges are anticipated with regards to technical usability and pedagogical usability. Published studies in Appendix D and Appendix F (attached to this thesis) were carried out using off-the-shelf native software applications for iPad. Even though a combination of those applications could support the P2PASS, test users (students) encountered difficulties to use them because the applications were not specifically designed for that purpose. Students suggested that we design an integrated platform to improve handling of mathematical symbols and support for P2PASS process on iPad. This chapter describes the design principles that we used to develop an integrated and technically usable P2PASS system for the iPad. We further discuss the pedagogical usability of integrating the P2PASS into mathematics learning using mobile tablet technology. The chapter also discusses the limitations and the challenges for implementing such a technology based solution at university level.

## 4.2 Designing with students as co-designers

P2PASS is a student centred approach to learning, with students playing a key role in the learning process. Students are considered as the primary users of the technology supported P2PASS solution. Therefore we have included them in a complete development process, from initial concept, pre-design user and task analysis, system development and final design.

Figure 4.1: Iterative design process.

Inspired by the *User Centred Design Processes* (ISO 13407), Figure 4.1 shows an iterative design process that we carried out, with regular inputs from the users (students). The work we published in Paper II (Appendix C of this thesis) reports on

the users' perceptions on the initial concept of involving students in their formative assessment using mobile tablet technology. The overall results were encouraging and the students helped to define the steps of the P2PASS process as shown in Figure 4.2.

```
┌─────────────────────────────────────────────────────┐
│                      Teacher:                        │
│   •   Creates test questions and answers             │
│   •   Discusses peer-to-peer assessment process      │
│         with students                                │
│   •   Administers students' profiles and groups      │
└─────────────────────────────────────────────────────┘
                          │
                          ▼
┌─────────────────────────────────────────────────────┐
│       A set of questions is given to the students    │◄──┐
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
┌─────────────────────────────────────────────────────┐   │
│          Students work in groups of 3 to 4 students  │   │
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
┌─────────────────────────────────────────────────────┐   │
│   Each student submits own work to the system        │   │
│            via a Mobile tablet computer              │   │
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
┌─────────────────────────────────────────────────────┐   │
│   Each student receives the work from 3 peers        │   │
│              and assesses the work                   │   │
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
┌─────────────────────────────────────────────────────┐   │
│   Students compare feedback received from            │   │
│   their peers and the suggested correct answers      │   │
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
┌─────────────────────────────────────────────────────┐   │
│        The system compiles and stores the            │   │
│              performance grades                      │   │
└─────────────────────────────────────────────────────┘   │
                          │                                │
                          ▼                                │
              ╱ Has every ╲            NO    ┌──────────┐  │
             ╱   student    ╲ ─────────────► │New groups│──┘
             ╲  achieved the╱               │of students│
              ╲learning goal(s)?╱            │are formed │
                   │                         └──────────┘
                   ▼ YES
┌─────────────────────────────────────────────────────┐
│   Peer-to-peer assessment process is completed       │
└─────────────────────────────────────────────────────┘
```
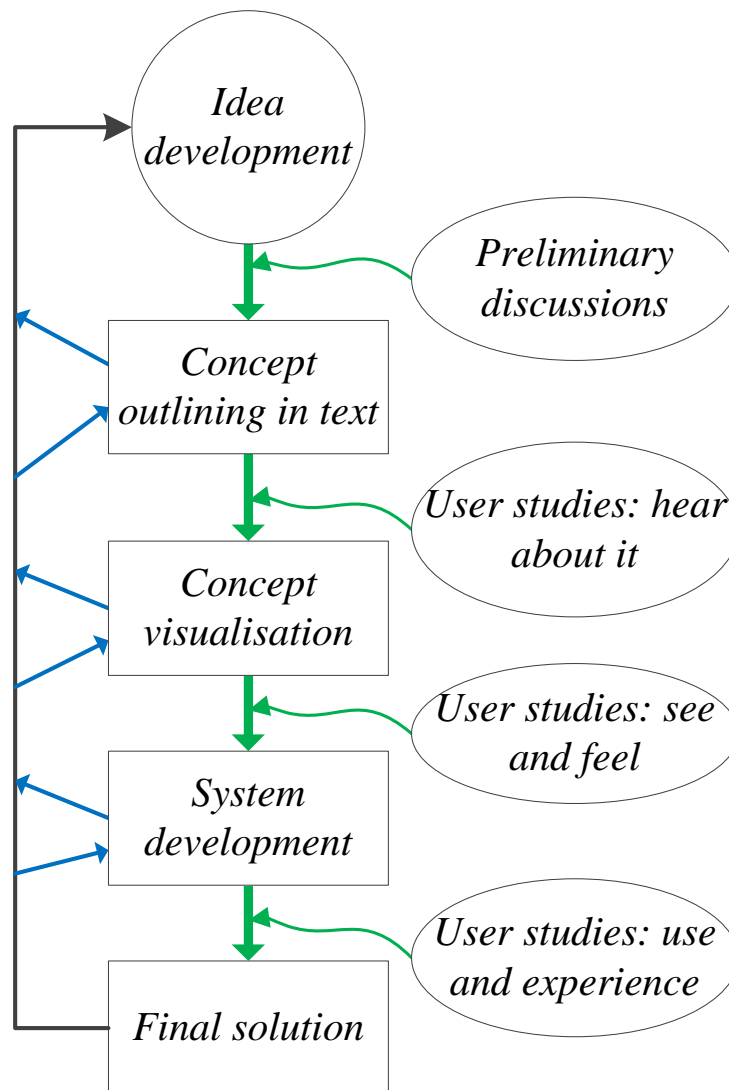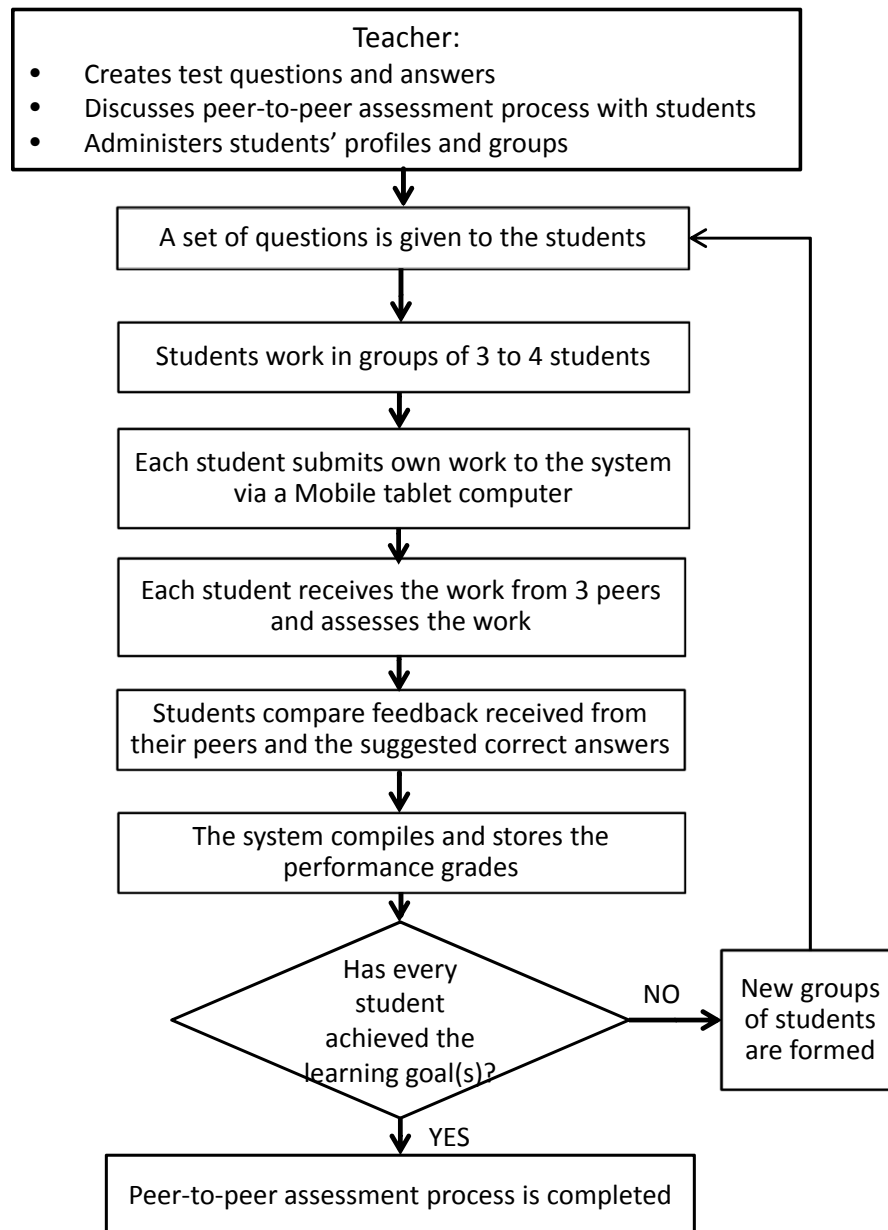
Figure 4.2: Peer-to-peer assessment process.

Based on user and organisational requirements obtained through interactions with students and two mathematics professors at UiA, we have produced a high level functional diagram presented in Figure 4.3. This functional diagram includes

a checkbox to validate whether every student has achieved the learning goals or not. Actually, being able to answer correctly to a mathematical task is not always the same thing as having achieved the learning goals; however since the assessment is done only on what the students have written, an assumption is made that the goal is to make sure every student can correctly answer the given questions. Subsequent to developing the functional diagram, we had to visualise the concept for the users. At this stage, we have designed user interfaces which were validated with test users and revised according to the users' feedback.
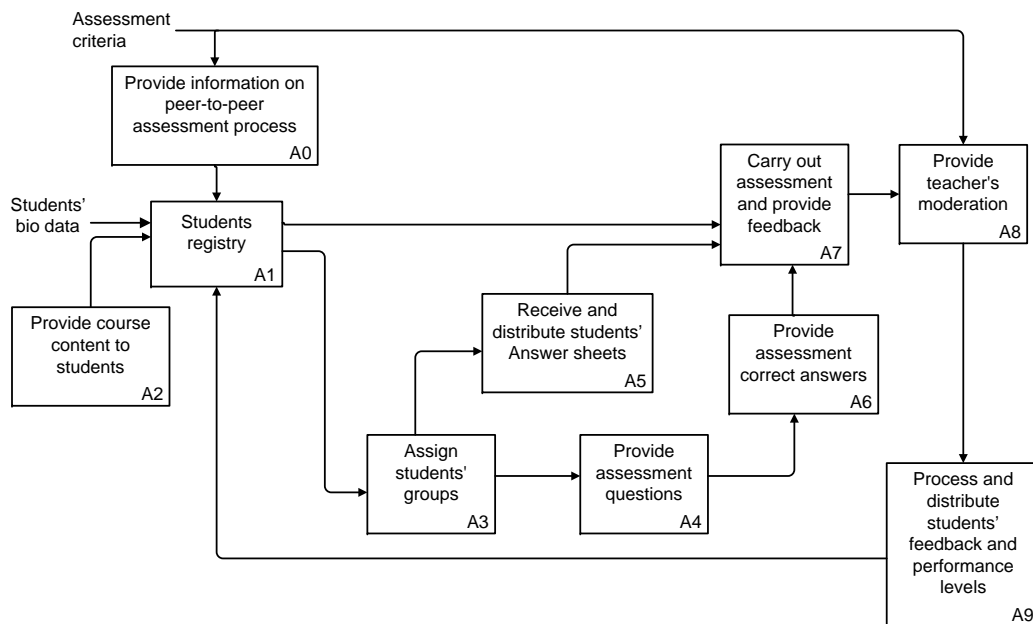


Figure 4.3: P2PASS solution high level functional diagram.

The goal of a usability test is to improve the usability of the product. We wanted to improve the usability of the user interfaces from the beginning, without spending too much efforts and resources. Hence, the first iteration of usability testing was done on low fidelity prototypes, with paper mockups. Although designers may choose to sketch paper prototypes by hand, we found it more efficient to use "Pencil" [93], a graphical user interface (GUI) prototyping tool to create mockups.

The user interfaces presented in Figure 4.4 and Figure 4.5 are taken from a paper prototype that was given to test users (students) during low fidelity test. We have employed the Cognitive Walkthrough (CW) evaluation technique because it is easily understandable and applicable [94][95] and "usually finds more real usability problems" [96, p.350]. CW is a usability inspection method that focuses on evaluating a User Interface (UI) design for ease of learning, particularly the exploratory

Figure 4.4: User interface prototype for providing feedback.

learning ("first time use without formal training") [97]. Using this technique, a representative team of students was required to go through the steps of a task scenario, with the prototype of P2PASS application in order to uncover process and workflow flaws and inconsistencies. Below is an indicative task scenario that was presented to a group of test users:

- Jan and Tonje, second year engineering students, participate in P2PASS of a mathematics subject. They start by registering their personal details on the P2PASS system, then answer a question paper from the current assignment and individually submit their answers after checking and correcting any mistakes. They usually revise the assessment criteria and assess each other's answers with reference to the teacher's answer sheet. Each one of them provides a feedback on the assessed work, and receives in return a feedback from the peer student.

CW technique is adopted because we wanted to identify specific problems at an early stage of design. Using this technique, we have uncovered mismatches between our task conceptualisation and the students' conceptualisation. Additionally, the wording on the menus and buttons was altered according to students' comments.

Figure 4.5: User interface prototype for receiving feedback.

For example, students suggested that a single button labeled "Complain" would be easier to use than having three buttons ("I agree", "Cancel", "I do not agree") for the students to say whether he/she is happy or not with the feedback received.

Following a series of user testing with the paper prototype, we have improved the affordance and visibility of the application, to allow users' actions to match the tasks' descriptions. Since certain aspects of the application can not be tested with a low fidelity prototype, there is a need to increase the fidelity of the prototype, to make the actions on prototype resemble more and more the real task. To achieve this, I have arranged the GUI created with a prototyping tool into a slide show with Microsoft Powerpoint presentation software. With a slide presentation, users were able to observe the task flows in a more realistic way, hence allowing them to uncover more design problems.

Given that our P2PASS solution was intended for a mobile platform, we had to make a choice between developing a native mobile application or a web based mobile application. Native mobile applications offer better user experience as they are tailored to meet specific device characteristics. The major issue with native mobile applications is that they are platform specific, hence there would be a need to

develop an application for each platform as students are not expected to possess the same kind of mobile devices.

Guhr et al. [98] reported that institutions of learning face issues to customise mobile applications for different devices and operating systems, because of variations in screen sizes, resolutions, multimedia handling, security and reliability that would require costly programming and updating efforts. Therefore, we have opted for developing a web-based application which can be supported by various devices, provided that they have a browser and Internet connection. This application, hereafter referred to as A-PASS (Agder Peer Assessment System) integrates all necessary functionalities to support the P2PASS process. The A-PASS user interface offers a tabbed navigation making the information easy to find [99] and faster navigation between pages on a limited screen size of the mobile tablet computer.

It is noted that our prototype implementation was optimised for the *Safari* browser on Apple iPad[1] devices. Test devices for usability studies consisted of the first and second generations of iPad running iOS 5. However, the application was also successfully tested on the Samsung Galaxy Tab2[2] which runs Android 4.0 (Ice Cream Sandwich) operating system. Additional tests were performed on Personal Computers running Microsoft Windows 7 operating system.

The user centred design of A-PASS endeavours to provide a user experience nearing to that of a native mobile application. In the work published in Paper 6 (Appendix G) we indicated that the user interface consists of webpages rendered to the browser using hyper text mark up language (HTML). The latest HTML version (HTML5) offers new elements such as the *canvas* which allow for structuring and presenting graphical content on the web. Using the canvas element and JavaScript code, it is possible to implement a drawable region in order to enable handwriting of mathematical symbols on the tablet computer touch interface. From the interaction point of view, the feature to draw or write with a finger or stylus pen offers an intuitive natural feel for the users. The additional option to provide text based reviews in A-PASS allows for flexibility in feedback provision.

---

[1]http://www.apple.com/ipad/
[2]http://www.samsung.com/global/microsite/galaxytab2/10.1/spec.html?type=find

## 4.3   User studies: technical and pedagogical usability of A-PASS

The involvement of users from early stages of the iterative design cycle has paid off in developing A-PASS. Regular evaluation of technical usability has been instrumental in improving the user experience. Great changes were progressively realised through iterations, particularly on the following usability criteria:

- Ease of learning (How easy can a user learn how to use a system?)

- Ease of use

- Effectiveness (ability to complete the given tasks) and

- Ability to recover from errors

Early on in design, test users were allowed to customise the application interface with selection of the wording on menus, graphical and colour coding as well as the interaction styles including sizing of the finger/pen drawable region and feedback data entry forms. Later on, with a high fidelity prototype, test users (students) were involved in authentic tasks, to answer and assess mathematics assignments on Laplace transformations as reported in Paper 6 (Appendix G). Test users performed *think aloud protocol* [100][101] for us to collect the information on the usability problems so that we can make design improvements. In addition to thinking aloud, users have written down usability problems on a piece of paper as they carried out the given tasks, but they have also used a survey questionnaire provided at the end of the test session in order to express in detail what they experienced during the test.

The usability evaluation method used in this study was very effective in finding problems. Students indicated usability issues with statements such as: "I can not find the assignment"; "when I try to choose assignment, I don't get any options to choose from"; "it does not show how many questions are in the test"; "*all skrift kommer ikke opp* (all writing is not coming up)"; " when we answer the questions, the window we are typing on should be bigger"; "can not view the feedback given to me"; "can't delete pages if I make too many unnecessarily"; " the *Clear* button is close to *Erase* and without a *confirmation dialog*"; "no *Eraser* button for the feedback writing (or *Clear* for that matter)"; " when I click *Submit review* button, there is no message that my review has been submitted"; "How do I know whether I have given a review to this task? Right now I am uncertain of whether I have submitted 5 or 0 reviews because I can't see/have any control over this" etc.

Based on the students' feedback, we have addressed usability problems in order

to achieve meaningful interactions [102] enabled by the web technology in general and the media tablets in particular. The authors in [102] suggest that, in the context of learning, a meaningful interaction is the one which leads to increased learning. The purpose of interaction referred to in A-PASS is to allow students to interact with content and collaborate with peers [103].

Knowing that "there is usually no single best design alternative" [104, p.249], the final A-PASS design strives to increase the quality of interaction in order to support the baseline learning theory of P2PASS, a theory rooted into Jean Piaget's constructivist theory of cognitive development [105]. Evaluation of the pedagogical aspects of A-PASS was eventually carried out through user studies, to find out if the system can lead to increased learning and facilitate student centred learning.

Given that A-PASS is technically usable, we can also evaluate its usefulness in terms of *utility* which "is the question of whether the functionality of the system in principle can do what is needed" [106, p.25]. Nokelainen [107] defined the *pedagogical usability* as a sub-concept of utility, which depends on the intentions of the students and teachers in a learning setting. Based on the pedagogical usability criteria developed in [107] and the work in [108], we have evaluated the following pedagogical aspects of A-PASS as shown in Table 4.1.

The pedagogical usability was typically evaluated by having five students perform peer-to-peer assessment using the A-PASS. The results obtained from this study can not be generalised since the limited number of users can not achieve statistically significant results. However, the main intention of the study was to find out whether the A-PASS concept shows promising results, which is the case. Pedagogical usability evaluation results presented in Figure 4.6 give us an indication that A-PASS can help to enhance mathematics learning as students interact with content and their peers in a collaborative learning environment. A student participating in the user studies mentioned an encouraging personal claim to say: *"Jeg syns det er en veldig god måte å lære på, og skulle gjerne hatt mer av det* (I think it's a very good way to learn and would like to have more of it)". Another student called forth the added value of the mobile technology supported P2PASS system in "getting feedback from other students, and having an easy opportunity to have all in one device to carry around instead of carrying lots of books." Some of the students also noticed the positive effects of group work, with short statements like "fast feedback is good."

Table 4.1: Pedagogical usability evaluation.

| Pedagogical usability criteria | Subjective user attitude test statement ( 5-Point Likert scale) |
|---|---|
| Critical and reflective learning | The peer assessment system requires me to think and answer the questions myself and then provide my own feedback on others' work |
| Mobile technology added value | Mobile technology supported peer assessment provides more learning opportunities with flexibility and collaboration in my learning |
| Timely and encouraging feedback | Peer assessment provides me with encouraging and timely feedback |
| Learning goal orientation | Peer assessment has the potential to bridge the gap between my level of achievement and the learning goals set by the teacher |
| Helping to revise learning material | The peer assessment system required me to use and revise the mathematics learning materials such as books and lecture notes |
| Collaboration in problem solving | Peer assessment system encourages collaboration and it allows me to work with others in solving the problems |
| Learning short and easy to remember units | Peer assessment allows me to learn mathematics in short and meaningful units of learning; hence I can easily remember what I learn. |
| Motivation | Peer assessment system is interesting and it motivates me to achieve better results |
| Student activity in learning | Peer assessment system makes me more interested in learning and makes me more active in learning the mathematics |
| Learning efficiency | When I do the peer assessment, it takes less time to learn mathematics and reach the learning goals |

## 4.4   Limitations and implications for practice

Our study on mobile technology supported P2PASS promises to enhance mathematics learning. However, our experience in designing and implementing A-PASS calls for attention on key issues that should be considered in order to achieve increased learning with A-PASS:

1. *User aspects*:  Our study was challenged by the limited availability of students as test users. Trials with a larger sample users would have been better. But, given the time limits of a PhD research project and the availability of

**Students opinions on Pedagogical usability of A-PASS**

| Pedagogical usability criteria | |
|---|---|
| Critical and reflective thinking | 4,2 |
| Mobile technology added value | 4,0 |
| Timely and encouraging feedback | 3,8 |
| Learning goal orientation | 3,8 |
| Helps to revise the learning material | 3,6 |
| Collaboration in problem solving | 3,6 |
| Learn short & easy to remember units | 3,6 |
| Motivation | 3,2 |
| Student activity in learning | 3,2 |
| Learning efficiency (less time usage) | 2,8 |

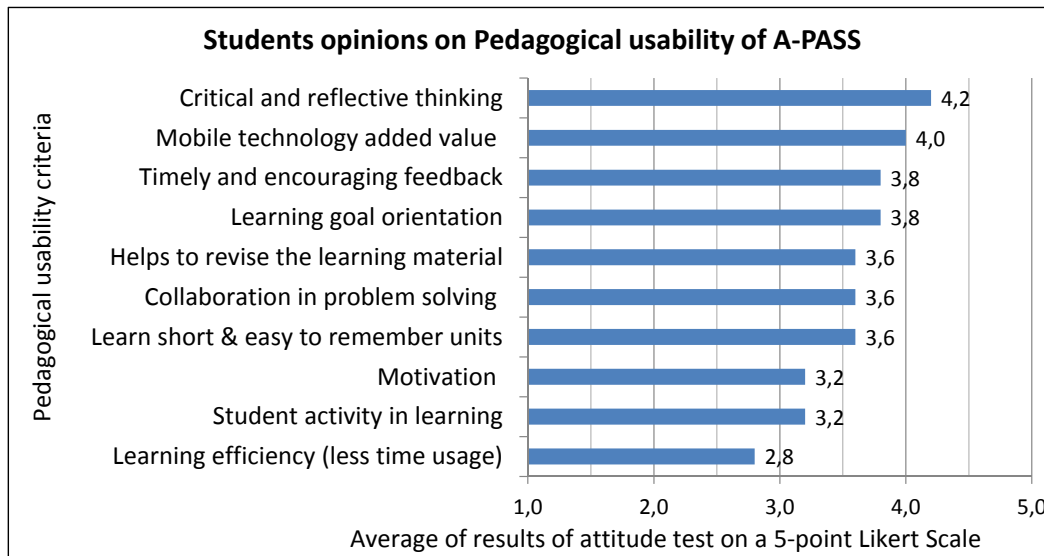Average of results of attitude test on a 5-point Likert Scale

Figure 4.6: Pedagogical usability of A-PASS.

students, I had to work with a limited number of students. If the final version of A-PASS solution is decided to be deployed, students would have to use it as part of a mathematics course.

2. *Technology aspects*: The technology aspects here considered, are closely related to the practical acceptability, involving the cost, compatibility, reliability and technical usability as discussed by Nielsen [106]. Practical implementation of A-PASS heavily depends on the availability and reliability of wireless network infrastructure because all the mobile tablet computers must be connected to a centralised server. The cost of maintaining network connectivity, maintenance of A-PASS software and investment in high end mobile tablet devices can be a challenge given that every student should have access to a tablet computer. Handling of mathematical handwritings requires a decent tablet device in terms of processing power, memory size, screen size and graphics memory: the mobile tablet Technology Readiness Level (TRL) [109] has to be improved in order to enhance responsiveness, efficiency and subjective user satisfaction. Even though it was a single incidence, technical difficulties might have led to one of the students suggesting to "write with pen and paper, take an image with iPad camera and upload" for easy and efficient use of iPad in P2PASS.

3. *Pedagogy aspects*: A-PASS offers a novel approach to teaching and learning mathematics. Successful implementation of P2PASS process as a form

of formative assessment requires commitment and clear understanding from students and teachers as well. Dunn et. al. [110] claimed that unproven methods of formative assessment may lead to losses of time, money and other resources that would be otherwise used to improve students' achievement. The overlap and confusions regarding definitions and the concept of formative assessment [111] can also mislead its practitioners. In our studies, students have shown evidence for the need to train them in assessment skills to ensure fairness and objectivity. The quality and hence the usefulness of feedback, is affected by the students' understanding of the assessment criteria as well as the educational goal of P2PASS.

4. *Institutional policy aspects*: Studies on A-PASS were done on a voluntary basis, and we found that both students and at least three mathematics teachers at UiA were unaware of this kind of formative assessment process. The integration of P2PASS into pedagogical practices in the classroom requires clear policy statements on issues such as participants' rights and responsibilities and positioning of formative assessment in the curriculum. Additionally, successful implementation of A-PASS would greatly depend on the teaching staff ability and willingness to use the system. Teachers would need time to prepare the mathematics questions and answers as well as managing the peer-assessment process.

## 4.5   Chapter summary and conclusion

Research efforts into new technology supported pedagogy enable the design of new tools for enhancing students' achievement. This chapter presented a student centred approach to designing a mobile technology supported system for mathematics learning. Since students are the expected users of the system, they play a key role in concept development, pre-design user and task analysis, system development (software coding), as well as usability testing. The involvement of students in the iterative design process was effective in finding usability problems of A-PASS early on.

Time and resources constraints have not allowed to extend user studies in order to confirm more firm pedagogical benefits of using A-PASS. Results of the pedagogical usability study indicate a potential for enabling increased learning through meaningful interactions. Students, teachers and leaders of educational institutions should all be engaged in order to positively integrate P2PASS into the educational practices.

# Chapter 5

# Summary of contributions and future directions

## 5.1   Major contributions

This PhD study combined two areas of research: ICT research and mathematics education. This thesis is a contribution unifying the two worlds, and an attempt to find how ICT can be used in enhancing student learning of mathematics.

The University of Agder is a modern university and well suited to develop and test new learning tools. This work contributed to the difficult task of assessing mathematics in order to provide high quality feedback to students, and engaging them more into learning. The research work reported in this thesis studied the possibilities of involving students in assessment of mathematics tasks. For teachers and students to work efficiently, mobile and web technology was chosen to build an electronic assessment system with serious consideration of *human factors* in learning.

Assessment is a broad field of research in mathematics education. This thesis presented a solution of how assessment can be practically done at the university level, and to promote students' engagement and responsibility in learning. This solution, called Agder Peer Assessment System (A-PASS), can also be used at high school level provided that students are well equipped with necessary assessment skills.

The findings of this study indicate that there are benefits of students learning together with their peers in different ways, peer-to-peer assessment (P2PASS) being one of them. Students showed willingness to assist each other not only by assessing their work but also helping each other to find the relevant learning materials, be it

from the class notes or Internet based learning resources such as the Wikipedia[1].

In P2PASS students explicitly assessed their peers' answers to mathematics questions, with the goal of indicating whether the answers were correct or not, and most importantly to point out the shortcomings and how they could be addressed. In P2PASS students implicitly assessed their peers' learning and understanding of mathematics. The study focused on finding out if students could better learn and understand mathematics themselves through assessing each other's work.

This study discussed practical scenarios of doing P2PASS in mathematics education. It underlined the importance of students' ownership of the peer assessment process. Students need to clearly understand the assessment process and the assessment criteria, with specifics of what to assess and how to rate the achievement levels. While most students preferred a simplified rating scheme (low, medium, high), some chose to use a numerical scale such as from 0 to 5. The simplified scale proved to be more helpful compared to the numerical one.

The purpose of peer assessment should be explained to students, to clarify that, in this case, it is done for formative rather than summative purposes. The P2PASS process requires collaborative efforts in order to be successful; every student participant needs to be as objective and fair as possible in order to provide meaningful, fair and useful feedback.

Students are not necessarily experts in the field of mathematics and they might have not learnt mathematics correctly themselves. Therefore, they may need a reference answersheet from the teacher to avoid giving inappropriate comments/ assessments to their fellow students. Since the assessment is carried out anonymously, students should be made aware that the teacher has a possibility to link a feedback to the assessor. This option can allow the teacher to appreciate students' achievement, and to prevent bullying and other forms of misuse.

A-PASS allowed assessing students' achievement on tasks in mathematics, based on their written answers. However, students may know more than what they are able to write and communicate. Additionally, they may know more than what can be explicitly assessed in a questionnaire. Regular peer assessments can provide opportunities for students to be assessed on a broad body of knowledge, with more possibilities to express themselves both through their own answers and review comments (feedback) on their peers' work.

By involving students in all phases of this study, it was found that students are likely to adopt a mobile tablet technology supported peer assessment solution for learning mathematics. Students indicated the expected usefulness and ease of use

---

[1]http://no.wikipedia.org/wiki/Laplacetransformasjon

of A-PASS. They expressed their intention to use the A-PASS because it is easy to use and easy to learn.

A-PASS was designed and successfully tested as a proof of concept. The usability of A-PASS gradually improved following an iterative design process, through which designs were consistently adjusted to meet the users' requirements. User studies indicated that with the advancement in both hardware and software technology, a large scale solution could be envisaged in the near future.

Studies in two countries, Norway and Rwanda, indicated institutional willingness to accept solutions such as the A-PASS. Currently universities are moving towards full digital solutions (i.e. digital media support in teaching, learning and administration). Students and teachers are interested to adopt new methods of teaching and learning, including new forms of assessment like P2PASS. Successful implementation of A-PASS requires increased awareness about the benefits of peer assessment among mathematics teachers and students.

In summary, the study achieved the goal to involve students more deeply into studying mathematics and assisting teachers in providing critical feedback to their students.

## 5.2 Future directions

This dissertation addressed peer to peer assessment of mathematics in a digital learning environment. However, in order to explore further the benefits of such pedagogical approach in the future, the following points need to be considered:

**Deploy for a complete course:** Redesign one of the mathematics courses in order to make peer-to-peer assessment an integrated part of it using the A-PASS tool. This is to prepare a large scale trial.

**Long term comparative study:** Design a long term comparative study involving one group of students using A-PASS tool and another (reference) group of students without using the tool. The result of that study would clearly document the qualitative and quantitative advantages/ drawbacks of peer-to-peer feedback based on A-PASS.

**Evolve overall solution:** Invest time and resources to enhance the peer-to-peer assessment method, functionality, technology framework and usability of A-PASS.

# REFERENCES

[1] Exemplars, "Classic Math Rubric,", [Online]. http://www.exemplars.com/assets/files/math_rubric.pdf, 2006. Retrieved 21.5.2012.

[2] G. Egodawatte, "A rubric to self-assess and peer-assess mathematical problem solving tasks of college students," *Acta Didactica Napocensia*, vol. 3, no. 1, pp. 75–88, 2010.

[3] G. Maslen, "Worldwide student numbers forecast to double by 2025,", [Online]. Available: http://www.universityworldnews.com/article.php?story=20120216105739999, February 2012. Retrieved on 03/10/2012.

[4] Institute of Education Sciences National Center for Education Statistics, "Tuition costs of colleges and universities,", [Online]. Available: http://nces.ed.gov/fastfacts/display.asp?id=76, September 2012. Retrieved on 03/10/2012.

[5] E. Hovdhaugen, "Transfer and dropout: different forms of student departure in Norway," *Studies in Higher Education*, vol. 34, no. 1, pp. 1–17, 2009.

[6] G. Paton, "University drop-out rate soars by 13 percent in a year,", [Online]. Available: http://www.telegraph.co.uk/education/educationnews/9173784/University-drop-out-rate-soars-by-13pc-in-a-year.html, October 2012 . Retrieved 05/10/2012.

[7] M. De Paola and V. Scoppa, "The Effects of Class Size on the Achievement of College Students," *The Manchester School*, vol. 79, no. 6, pp. 1061–1079, Blackwell Publishing Ltd, 2011.

[8] E. C. Kokkelenberg, M. Dillon, and S. M. Christy, "The effects of class size on student grades at a public university," *Economics of Education Review*, vol. 27, no. 2, pp. 221 – 233, 2008.

[9] D. A. Cheng, "Effects of class size on alternative educational outcomes across disciplines," *Economics of Education Review*, vol. 30, no. 5, pp. 980–990, Special Issue on Education and Health, 2011.

[10] F. Dochy, M. Segers, and D. Sluijsmans, "The use of self-, peer and co-assessment in higher education: A review," *Studies in Higher Education*, vol. 24, no. 3, pp. 331–350, 1999.

[11] O. McGarr and A. M. Clifford, "Just enough to make you take it seriously: exploring students attitudes towards peer assessment," *The International Journal of Higher Education Research*, pp. 1–17, September 2012.

[12] C. Dreher, T. Reiners, and H. Dreher, "Investigating Factors Affecting the Uptake of Automated Assessment Technology," *Journal of Information Technology Education*, vol. 10, pp. 161 – 181, 2011.

[13] L. Chirwa, "A case study on the impact of automated assessment in engineering mathematics," *Engineering education*, vol. 3, no. 1, pp. 13 – 20, 2008.

[14] J. C. W. Debuse, M. Lawley, and R. Shibl, "Educators perceptions of automated feedback systems," *Australasian Journal of Educational Technology*, vol. 24, no. 4, pp. 374–386, 2008.

[15] B. Sandene, N. Horkay, R. Bennett, N. Allen, J. Braswell, B. Kaplan, and A.Oranje, "Online Assessment in Mathematics and Writing: Reports From the NAEP Technology-Based Assessment Project, Research and Development Series (NCES 2005457)," *U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office*, August 2005.

[16] N. A. Chaoui, *Finding Relationships Between Multiple-Choice Math Tests and Their Stem-Equivalent Constructed Responses*, PhD thesis, Claremont Graduate University, 2011.

[17] F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models," *Management Science*, vol. 35, no. 8, pp. 982–1003, Aug. 1989.

[18] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User Acceptance of Information Technology: Toward a Unified View," *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, Sept. 2003.

[19] S. A. Vannoy and P. Palvia, "The Social Influence Model of Technology Adoption," *Communications of the ACM*, vol. 53, no. 6, pp. 149–153, June 2010.

[20] Y. Malhotra and D. F. Galetta, "Extending the Technology Acceptance Model to Account for Social Influence: Theoretical Bases and Empirical Valida-

tion," in *Proc. 32$^{nd}$ Hawaii International Conference on System Sciences*, 1999, pp. 1–14.

[21] B. Niehaves, E. Gorbacheva, and R. Plattfaut, "Social Aspects in Technology Acceptance: Theory Integration and Development," in *Proceedings of the 45th Hawaii International Conference on System Sciences*, Jan. 2012, pp. 3149–3158.

[22] G. *ONeill* and T. McMahon, "Student-centred learning: What does it mean for students and lecturers?,", [Online]. Available: http://www.aishe.org /readings/2005-1/oneill-mcmahon-Tues_19th_Oct_SCL.pdf, 2005. Retrieved 08/11/2012.

[23] P. Dillenbourg, "Virtual Learning Environments," in *EUN Conference 2000: Learning in the new millenium: Building new education strategies for schools*, 2000.

[24] G. Piccoli, R. Ahmad, and B. Ives, "Web-Based Virtual Learning Environments: A Research Framework and a Preliminary Assessment of Effectiveness in Basic IT Skills Training," *MIS Quarterly*, vol. 25, no. 4, pp. pp. 401–426, Management Information Systems Research Center, University of Minnesota, 2001.

[25] S. J. H. Yang, "Context Aware Ubiquitous Learning Environments for Peer-to-Peer Collaborative Learning," *Educational Technology & Society*, vol. 9, no. 1, pp. 188–201, 2006.

[26] P. Twining, *Researching IT in Education*, chapter Educational information technology research methodology: Looking back and moving forward, pp. 153–168, Routledge, 2010.

[27] A. F. Chalmers, *What is this thing called Science?*, chapter Science as knowledge derived from the facts of experience, pp. 1–18, Hackett Publishing Company, Inc., 3 edition, 1999.

[28] H. R. Beyer, *Encyclopedia of Software Engineering*, vol. 2, chapter User-Centered Design, pp. 1308–1317, Taylor & Francis, 2010.

[29] E. G. Toms, *User-Centered Design of Information Systems*, chapter 538, pp. 5452–5460, Taylor & Francis, 2011.

[30] J. Nielsen, "Iterative User Interface Design," *IEEE Computer*, vol. 26, no. 11, pp. 32–41, Nov. 1993.

[31] S. Krug, *Don't make me think! A common sense approach to web usability*. New Riders Publishing, Berkeley, CA, 2 edition, 2006.

[32] T. R. Black, *Doing Quantitative Research in the Social Sciences*. SAGE Publications Ltd, 2005.

[33] M. E. Brenner, *Handbook of Complementary Methods in Education Research*, chapter Interviewing in Educational Research, pp. 357 – 370, Lawrence Erlbaum Associates, Inc., 2006.

[34] J. Lazar, J. H. Feng, and H. Hochheiser, *Research Methods in Human-Computer Interaction*. Wiley, 2010.

[35] S. Kujala and M. Kauppinen, "Identifying and selecting users for user-centered design," in *Proc. 3$^{rd}$ Nordic conference on Human-computer interaction*, New York, NY, USA, 2004, ACM, NordiCHI '04, pp. 297–303.

[36] C. W. Turner, J. R. Lewis, and J. Nielsen, "Determining usability test sample size," *International Encyclopedia of Ergonomics and Human Factors*, vol. 3, no. 2, pp. 3084–3088, 2006.

[37] C. Robson, *Real World Reasearch. A Resource for Social Scientists and Practitioner-Researchers*. Blackwell Publishers Inc., 2 edition, 2002.

[38] J. Nielsen, "How Many Test Users in a Usability Study?,", [Online]. Available: http://www.useit.com/alertbox/number-of-test-users.html, June 2012 . Retrieved on 12/11/2012.

[39] R. M. Alvarez and C. VanBeselaere, "Web-Based Survey,", in *Encyclopedia of Social Measurement*, Kimberly Kempf-Leonard, Ed., pp. 955 – 962, Elsevier, New York, 2005.

[40] M. M. Hayslett and B. M. Wildemuth, "Pixels or pencils? The relative effectiveness of Web-based versus paper surveys," *Library & Information Science Research*, vol. 26, no. 1, pp. 73 – 93, 2004.

[41] H. Huang, "Do print and Web surveys provide the same results?," *Computers in Human Behavior*, vol. 22, no. 3, pp. 334 – 350, 2006.

[42] W. Fan and Z. Yan, "Factors affecting response rates of the web survey: A systematic review," *Computers in Human Behavior*, vol. 26, no. 2, pp. 132 – 139, 2010.

[43] J. Nielsen, "First Rule of Usability? Don't listen to Users.", [Online]. Available: http://www.useit.com/alertbox/20010805.html, August 2001. Retrieved 18/10/2012.

[44] S. Love, *Understanding Mobile Human-Computer Interaction*. Elsevier Ltd., 2005.

[45] J. Nielsen, *Usability Engineering*. Morgan Kaufmann, 1993.

[46] J. R. Koetting and M. Malisa, *Handbook of Research on Educational Communications and Technology*, chapter Philosophy, Research and Education, pp. 1010–1020, Lawrence Erlbaum Associates, Inc., 2 edition, 2004.

[47] W. C. Savenye and R.S. Robinson, *Handbook of Research on Educational Communications and Technology*, chapter Qualitative Research Issues and Methods: An Introduction for Educational Technologists, pp. 1045–1071, Lawrence Erlbaum Associates, Inc., 2004.

[48] J. W. Miller, L. P. Martineau, and R.C. Clark, "Technology Infusion and Higher Education: Changing Teaching and Learning," *Innovative Higher Education*, vol. 24, no. 3, 2000.

[49] M. K. Smith and K. K. Perkins, "At the end of my course, students should be able to : The benefits of creating and using effective learning goals," *Microbiology Australia*, pp. 35–37, 2010.

[50] L. Jiang and J. Elen, "Why do learning goals (not) work: a reexamination of the hypothesized effectiveness of learning goals based on students behaviour and cognitive processes," *Educational Technology Research and Development*, vol. 59, pp. 553–573, 2011.

[51] H. Coates, R. James, and G. Baldwin, "A critical examination of the effects of learning management systems on university teaching and learning," *Tertiary Education and Management*, vol. 11, no. 1, pp. 19–36, 2005.

[52] S. Lonn and S. D. Teasley, "Saving time or innovating practice: Investigating perceptions and uses of Learning Management Systems," *Computers &amp; Education*, vol. 53, no. 3, pp. 686 – 694, 2009.

[53] S. Lonn, S. D. Teasley, and A. E. Krumm,  "Who needs to do what where?: Using learning management systems on residential vs. commuter campuses," *Computers & Education*, vol. 56, no. 3, pp. 642 – 649, 2011.

[54] G. Naveh, D. Tubin, and N. Pliskin, "Student satisfaction with learning management systems: a lens of critical success factors," *Technology, Pedagogy and Education*, vol. 21, no. 3, pp. 337–350, 2012.

[55] C. M. Christensen, M.B. Horn, and C.W. Johnson,  *Disrupting Class - How Disruptive Innovation Will Change the Way the World Learns*. The McGraw-Hill, 2008.

[56] T. C. Reeves,  *Computer education: New Perspectives*, chapter Evaluating What Really Matters in Computer-Based Education, pp. 219–246,  MAS-TEC, Perth, Australia, 1994.

[57] D. H. Jonassen, K. L. Peck, and B. G. Wilson, *Learning with technology: A constructivist perspective*. Prentice Hall, New Jersey, USA., 1999.

[58] S. R. Hiltz,  "Teaching in a Virtual Classroom," *International Journal of Educational Telecommunications*, vol. 1, no. 2, pp. 185–198, 1995.

[59] H. Rajaei and A. Aldhalaan, "Advances in virtual learning environments and classrooms,"  in *Proc. 14$^{th}$ Communications and Networking Symposium*, San Diego, CA, USA, 2011, Society for Computer Simulation International, CNS '11, pp. 133–142.

[60] W. Premchaiswadi, A. Tungkasthan, and N. Jongsawat, "Enhancing learning systems by using virtual interactive classrooms and web-based collaborative work," in *Education Engineering (EDUCON), 2010 IEEE*, 2010, pp. 1531–1537.

[61] J.-V. Benlloch-Dualde, F. *Buendía*, and J.-C. Cano, "On the Design of Interactive Classroom Environments based on the Tablet PC Technology," in *40$^{th}$ ASEE/IEEE Frontiers in Education Conference*, 2010, pp. T4C–1 – T4C–6.

[62] D. Zhang, J. L. Zhao, L. Zhou, and J.F. Jr. Nunamaker,  "Can e-learning replace classroom learning?," *Commun. ACM*, vol. 47, no. 5, pp. 75–79, ACM,  May 2004.

[63] E. T. Welsh, C. R. Wanberg, K. G. Brown, and M. J. Simmering, "E-learning: emerging uses, empirical results and future directions," *International Journal*

*of Training and Development*, vol. 7, no. 4, pp. 245–258, Blackwell Publishing Ltd., 2003.

[64] H. C. Williams, "A Review of Ubiquitous Learning," *The Information Society*, vol. 28, no. 2, pp. 121–122, 2012.

[65] M. J. Koehler and P. Mishra, "What Is Technological Pedagogical Content Knowledge?," *Contemporary Issues in Technology and Teacher Education*, vol. 9, no. 1, pp. 60–70, 2009.

[66] E. von Glasersfeld, "Cognition, Construction of Knowledge, and Teaching," *Syntheses (special issue on education)*, vol. 80, no. 1, pp. 121–140, 1989.

[67] V. Garaj, "m-Learning in the Education of Multimedia Technologists and Designers at the University Level: A User Requirements Study," *Learning Technologies, IEEE Transactions on*, vol. 3, no. 1, pp. 24 –32, jan.-march 2010.

[68] R. Cobcroft, S. Towers, J. Smith, and A. Bruns, "Literature review into mobile learning in the university context,", [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/
download?doi=10.1.1.93.2617&rep=rep1&type=pdf, Jan 2006. Retrieved 27/11/2012.

[69] D. Corlett, M. Sharples, S. Bull, and T. Chan, "Evaluation of a mobile learning organiser for university students," *Journal of Computer Assisted Learning*, vol. 21, no. 3, pp. 162–170, Blackwell Science Ltd, 2005.

[70] A. Giemza, P. Verheyen, and H. U. Hoppe, "Challenges in Scaling Mobile Learning Applications: The Example of Quizzer," in *2012 Seventh IEEE International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, IEEE, 2012.

[71] Y. Park, "A Pedagogical Framework for Mobile Learning: Categorizing Educational Applications of Mobile Technologies into Four Types," *International Review of Research in Open and Distance Learning*, vol. 12, no. 2, February 2011.

[72] F. Xhafa and S. Caballé, "Implementing a Mobile Campus Using MLE Moodle," in *2010 International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, Fukuoka, Japan., 2010, IEEE Computer Society, pp. 207–214.

[73] L. Sha, C.-K. Looi, W. Chen, and B. H. Zhang, "Understanding mobile learning from the perspective of self-regulated learning," *Journal of Computer Assisted Learning*, vol. 28, pp. 366–378, 2012.

[74] A. Y. Kolb and D. A. Kolb, "The Kolb Learning Style Inventory -Version 3.1 2005 Technical Specifications,", [Online]. Available: http://www.whitewater-rescue.com/support/pagepics/lsitechmanual.pdf, May 2005. Retrieved 06/12/2012.

[75] R. A. Wisher, *Learner-centered theory and practice in distance education. Cases from higher education.*, chapter Learning in the Knowledge age: Up-Front or at a Distance, pp. 183–197, Lawrence Erlbaum Associates, Inc., 2004.

[76] P. Black and D. Wiliam, "Assessment and Classroom Learning," *Assessment in Education: Principles, Policy & Practice*, vol. 5, no. 1, pp. 7–74, 1998.

[77] C. Aoun, "Peer-assessment and learning outcomes : product deficiency or process defectiveness?," in *Proceedings of the 34$^{th}$ International Association for Educational Assessment (IAEA) Annual Conference*, Cambridge, UK., Sept 2008, University of Cambridge Local Examinations Syndicate (UCLES), pp. 1–8.

[78] D. R. Sadler, "Formative Assessment: revisiting the territory," *Assessment in Education*, vol. 5, no. 1, pp. 77–84, 1998.

[79] T. R. Guskey, *Handbook of Formative Assessment*, chapter Formative assessment. The contributions of Benjamin S. Bloom, pp. 106–124, Routledge, 2010.

[80] J. Hattie and H. Timperley, "The Power of Feedback," *Review of Educational Research*, vol. 77, no. 1, pp. 81–112, 2007.

[81] D. J. Nicol and D. Macfarlane-Dick, "Formative assessment and self-regulated learning: a model and seven principles of good feedback practice," *Studies in Higher Education*, vol. 31, no. 2, pp. 199–218, 2006.

[82] J. Sitthiworachart and M. Joy, "Web-based peer assessment in learning computer programming," in *Proceedings of the 3rd IEEE International Conference on Advanced Learning Technologies (ICALT '03).*, 2003, pp. 180–184.

[83] N. Falchikov and J. Goldfinch, "Student Peer Assessment in Higher Education: A Meta-Analysis Comparing Peer and Teacher Marks," *Review of Educational Research*, vol. 70, no. 3, pp. 287–322, 2000.

[84] R. Stiggins and J. Chappuis, "Using Student-Involved Classroom Assessment to Close Achievement Gaps," *11-18*, vol. 44, no. 1, pp. 11–18, 2005.

[85] R. J. Stiggins and J. Chappuis, *An introduction to student-involved assessment for learning*. Pearson, 6 edition, 2012.

[86] M. Niss, *Investigations into Assessment in Mathematics Education*, chapter Assessment in Mathematics Educations and its Effects:An Introduction, pp. 1–30, Kluwer Academic Publishers, 1993.

[87] R. A. Adams and C. Essex, *Calculus: A complete course*. Pearson Canada Incorporation., 2010.

[88] S. Cassidy, "Developing employability skills: peer assessment in higher education," *Education + Training*, vol. 48, no. 7, pp. 508–517, 2006.

[89] A. Chen, A. Mashhadi, D. Ang, and N. Harkrider, "Cultural Issues in the Design of Technology-Enhanced Learning Systems," *British Journal of Educational Technology*, vol. 30, no. 3, pp. 217–230, July 2002.

[90] M. Wild, "Editorial: Accomodating issues of culture and diversity in the application of new technologies," *British Journal of Educational Technology*, vol. 30, no. 3, pp. 195–199, July 1999.

[91] K. Walsh, "Is Reverse Instruction Education Technology⁏s Perfect Storm?,", [Online]. Avaialable: http://www.emergingedtech.com/2012/04/is-reverse-instruction-education-technologys-perfect-storm/, April 2012 . Retrieved 21/11/2012.

[92] M. J. Lage, G. J. Platt, and M. Treglia, "Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment," *The Journal of Economics Education*, vol. 31, no. 1, pp. 30–43, 2000.

[93] Evolution Solutions Co. Ltd., "Pencil,", [Online]. Available: http://evolus.vn/en-US/Products/Pencil.aspx, 2009.

[94] M. Franzke, "Using the cognitive walkthrough in iterative design," in *Posters and Short Talks of the 1992 SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 1992, ACM, CHI '92, pp. 37–37.

[95] B. E. John and H. Packer, "Learning and using the cognitive walkthrough method: a case study approach," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 1995, ACM Press/Addison-Wesley Publishing Co., CHI '95, pp. 429–436.

[96] E. Liljegren, "Usability in a medical technology context assessment of methods for usability evaluation of medical equipment," *International Journal of Industry Ergonomics*, pp. 345–352, 2006.

[97] J. Rieman, M. Franzke, and D. Redmiles, "Usability evaluation with the cognitive walkthrough," in *Conference Companion on Human Factors in Computing Systems*, New York, NY, USA, 1995, ACM, CHI '95, pp. 387–388.

[98] D. J. Guhr and G. A. Gair, "Mobile device trends and their implications for mobile learning at higher education institutions," in *IADIS International Conference Mobile Learning 2012*, Berlin, Germany, March 2012, pp. 347–350.

[99] A. Burrell and A. C. Sodan, "Web Interface Navigation Design: Which Style of Navigation-Link Menus Do Users Prefer?," in *Proceedings of the 22nd International Conference on Data Engineering Workshops (ICDEW'06)*, Atlanta, GA, USA, April 2006, p. 42.

[100] A. M. Gill and B. Nonnecke, "Think aloud: effects and validity," in *Proceedings of the 30th ACM international conference on Design of communication*, New York, NY, USA, 2012, ACM, SIGDOC '12, pp. 31–36.

[101] J. Nielsen, T. Clemmensen, and C. Yssing, "Getting access to what goes on in people's heads?: reflections on the think-aloud technique," in *Proceedings of the second Nordic conference on Human-computer interaction*, New York, NY, USA, 2002, ACM, NordiCHI '02, pp. 101–110.

[102] Y. Woo and T. C. Reeves, "Meaningful interaction in web-based learning: A social constructivist interpretation," *The Internet and Higher Education*, vol. 10, no. 1, pp. 15–25, 2007.

[103] P. Northrup, "A Framework for Designing Interactivity into Web-based Instruction," *Educational Technology*, vol. 41, no. 2, pp. 31–39, Mar-Apr 2001.

[104] A. Dix, J. Finlay, G. D. Abowd, and R. Beale, *Human-computer interaction*. Prentice Hall, 3 edition, 2004.

[105] E. von Glasersfeld, "An Interpretation of Piagetian's Constructivism," *Revue Internationale de Philosophie*, vol. 36, no. 4, pp. 612–635, 1982.

[106] J. Nielsen, *Usability Engineering*. Academic press, Boston, 1993.

[107] P. Nokelainen, "An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students," *Educational Technology & Society*, vol. 9, no. 2, pp. 178–197, 2006.

[108] S. Hadjerrouit, "A Conceptual Framework for Using and Evaluating Web-Based Learning Resources in School Education," *Journal of Information Technology Education*, vol. 9, pp. 53–79, 2010.

[109] M. S. Seablom and L. A. Lemmerman, "Measuring technology maturity and readiness for mission infusion," in *2012 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Munich, Germany, July 2012, pp. 5646– 5649.

[110] K. E. Dunn and S. W. Mulvenon, "A Critical Review of Research on Formative Assessment:The Limited Scientific Evidence of the Impact of Formative Assessment in Education," *Practical Assessment, Research & Evaluation*, vol. 14, no. 7, pp. 1–11, 2009.

[111] M. Filsecker and M. Kerres, "Repositioning Formative Assessment from an Educational Assessment Perspective: A Response to Dunn & Mulvenon (2009)," *Practical Assessment, Research & Evaluation.*, vol. 17, no. 16, pp. 1–9, December 2012.

# Part II

# Appendix A

# List of Publications

The author of this dissertation has published six peer-reviewed scientific articles during the course of the 3 years PhD programme, as a first author for all articles. The purpose of including this list, is to give the reader a quick overview of the articles in a chronological order of publication:

**Paper I** G. M. N. Isabwe, H. Øysæd, and F. Reichert, "Future Concepts for University Teaching and Learning," in *Proc. of IADIS International Conference Mobile Learning 2011*, Avila, Spain, 2011, pp. 307-309.

**Paper II** G. M. N. Isabwe, M. Carlsen, H. Øysæd, and F. Reichert, "On the Mobile Technology Enabled Peer-Evaluation: A User Centric Approach," in *Proc. 7$^{th}$ Annual International Conference on Computing and ICT Research (ICCIR11)*, Kampala, Uganda, 2011, pp. 272-285.

**Paper III** G. M. N. Isabwe, F. Reichert and M. Konnestad, "A Novel Approach to the Application of Semantic Web Technologies to Student Centred Learning," in *Proc. of IADIS Mobile Learning 2012*, Berlin, Germany, 2012, pp.296-301.

**Paper IV** G. M. N. Isabwe, F. Reichert and S. O. Nyberg, "Towards Integrating Technology Supported Peer-to-peer Assessments into Mathematics Education: Experiences with iPad Mobile Tablet Technology," in *Proc. of Computer Supported Education (CSEDU 2012)*, Porto, Portugal, 2012, pp.119-125.

**Paper V** G. M. N. Isabwe, "Investigating the usability of iPad mobile tablet in formative assessment of a mathematics course," in *Proc. IEEE International Conference on Information Society*, London, UK, 2012, pp. 39-44.

**Paper VI** G. M. N. Isabwe and F. Reichert, "Developing a formative assessment system for mathematics using mobile technology: A student centred approach," in *Proc. of IEEE International Conference on Education & E-Learning Innovations (ICEELI 2012)*, Sousse, Tunisia, 2012, pp.1-6.

# Appendix B

# Paper I

| | |
|---|---|
| **Title:** | Future Concepts for University Teaching and Learning |
| **Authors:** | **Ghislain Maurice Norbert Isabwe**, Halvard Øysæd and Frank Reichert |
| **Affiliation:** | University of Agder, Faculty of Engineering and Science, Jon Lilletuns vei 9, 4879 Grimstad, Norway |
| **Published in:** | *Proceedings of IADIS International Conference Mobile Learning 2011. Avila, Spain*, March 2011. |

B

B

# Future Concepts For University Teaching and Learning

Ghislain Maurice Norbert Isabwe; Halvard Øysæd and Frank Reichert

University of Agder

E-mails: {maurice.isabwe, halvard.oysad, frank.reichert}@uia.no

*Abstract* —**University teaching and learning in the $21^{st}$ century and beyond requires novel approaches to meet the imperatives of global challenges. With increasing numbers of university goers and a multitude of Information and Communication technologies, higher education institutions are embracing various technological innovations to enhance teaching and learning. This paper presents the state-of-the-art of university teaching, and provides new concepts for teaching and learning at university level. A novel technology enabled constructivist learning is proposed as a framework for future university teaching.**

*Keywords*—Mobile learning, active learning, collaborative learning.

## I. INTRODUCTION

Traditionally, teaching and learning is commonly characterized by knowledge transfer from a teacher (or instructor in some cases) to the learner. Formal learning, which is a form of structured and organised learning that is directed by someone else; generally involves learning in a relatively large group taught on a course of study. This type of learning implies limited teacher to learner interaction on an individual level and less collaboration among learners. Formal and conventional learning are teacher-centred transmission of knowledge based on lectures, books and printed lessons which are written in academic format that may not be suitable for each and every learner. Formal learning is still the primary form of learning in mainstream education.

Subsequently, during the last three decades educational technology has recorded a good level of development and penetration but mostly with a teacher at the centre of learning. Non-formal learning, based on new technology enabled pedagogical models, adds natural ways of learning to conventional and formal methods of learning. There is a great potential to improve learners' performance by using technology to make learning more individual, adaptive, natural, easily accessible and more efficient.

## II. STATE-OF-THE-ART

Teaching at university level requires new tools and methods to address the needs of its varied population in such a way that all learners can achieve their best. Today's teaching methods such as lectures, seminars, group work classes and supervised work are mainly room based, with emphasis on one way teaching from a centralized location despite the classroom embedded technology, such as data networks and audio visual solutions.

The concept of "Computer Assisted Instruction" (CAI) also known as Computer assisted learning (CAL), has emerged as a supplement to formal teaching, an improvement to traditional teaching. Collins et al. [1, p.49] claimed that computer technologies "can dramatically increase a student's access to information". They reported a significant increase of students' final exam grades as a result of CAI pedagogical effectiveness. In a separate study on CAL in medical education [3],it was suggested that provision must be made for the style of teaching of the course and the style of learning of students that are attending the course.

Early CAL systems could support on demand, self-paced and remote learning but there was no real time interaction and collaboration. Novel concepts of

B

e-learning, mobile-learning, virtual classrooms and interactive classrooms would encourage and support student participation in knowledge construction.

E-learning, a computer assisted learning/training, comprises of many forms of electronic learning and teaching. It has become very popular in online and distance learning programmes mostly due to its time and location flexibility, cost-effectiveness, knowledge reuse and sharing among others. Even though e-learning has many advantages [10][11], such as self-paced and learner centred learning; the lack of interaction (immediate feedback) and collaboration especially in asynchronous learning remains a problem.

Given the portability and wide availability of mobile devices, universities are increasingly adopting "Mobile learning" [2][7] [5] in addition to formal teaching and learning. It is believed [4] that mobile learning will enhance learners' engagement to create, access, revise and share course content thus enhancing learning motivation and ownership.

Furthermore, "virtual classrooms" are designed to enable real-time and on-demand multimedia content delivery as well as real-time engagement and feedback. Although it has been confirmed that synchronous learning improves real-time interaction [6], there are reports of challenges [9] in terms of student support, understanding curricular goals and technology limitations.

Another concept known as "Interactive classroom" offers interaction in a room based classroom. Several approaches have been proposed from classroom voting systems with multiple choice questions (MCQ), to classroom presenters and active learning classrooms. Interactive classrooms promote student centred active learning through real-time feedback provision, and content sharing among the learners and the teacher as well. Interactive classrooms can facilitate both summative and formative assessments, which not only stimulate discussion and enhance teacher/learners interaction but also provide performance statistics. The major weakness of this method is lack of learner-learner interaction which is very important especially in a constructivist perspective [8]. Another limitation of MCQ consists of "Close-ended questions".

### III. Future Teaching and Learning Concepts

Current education systems are generally teacher centred and lack sufficient collaboration. Future teaching should be foremost student centred. We propose that learning should be about exploration, self-motivation, collaboration, interaction and demand-driven.

B

Future teaching, through CAL systems, should foster learners' engagement, responsibility and ownership of their learning. It is in this regard that more efforts should be invested into the following aspects of learning:

1. Peer-to-peer learning: learner-learner interaction in large classrooms and/or different geographical locations, peer-evaluation;

2. Learning availability and flexibility: self-paced on-demand learning and real time virtual learning;

3. Group based learning: real and virtual classroom

4. Teacher to learner(s) interaction: learning facilitation, feedback provision.

Current trends in computer assisted learning are to move beyond traditional formal and passive learning towards non-formal, active, interactive and virtual learning through multimedia and communications technologies.

A collaborative, interactive constructivist learning environment could not only help students learn more actively and effectively but also enhance learners' leadership and responsibility in the learning process. Figure B.1 presents a future university teaching framework based on new technology enabled constructivist learning concepts. This approach puts emphasis on the potential of mobile devices in peer-to-peer learning whereby collaboration tools are considered for learners to carry out project based assignments.

Learner's ownership of learning is a key factor to achieve an effective student centred learning, a self-directed learning which leads to self-efficacy. Furthermore, assessment and progress control are important aspects of the learning process. Student self-assessment and/or self-evaluation enable learners to keep track of their learning progress and allow them to dedicate appropriate time and resources/efforts in order to timely achieve their goals. Hence, progress control tools should be an integral part of any efficacious constructivist learning system.

In addition to interactivity, collaboration and progress control; there are content format and delivery tools that contribute to overall learners' performance. Particularly, mobile learning is of special interest given its high potential to improve learners' performance through enabling classroom interaction and virtualization.
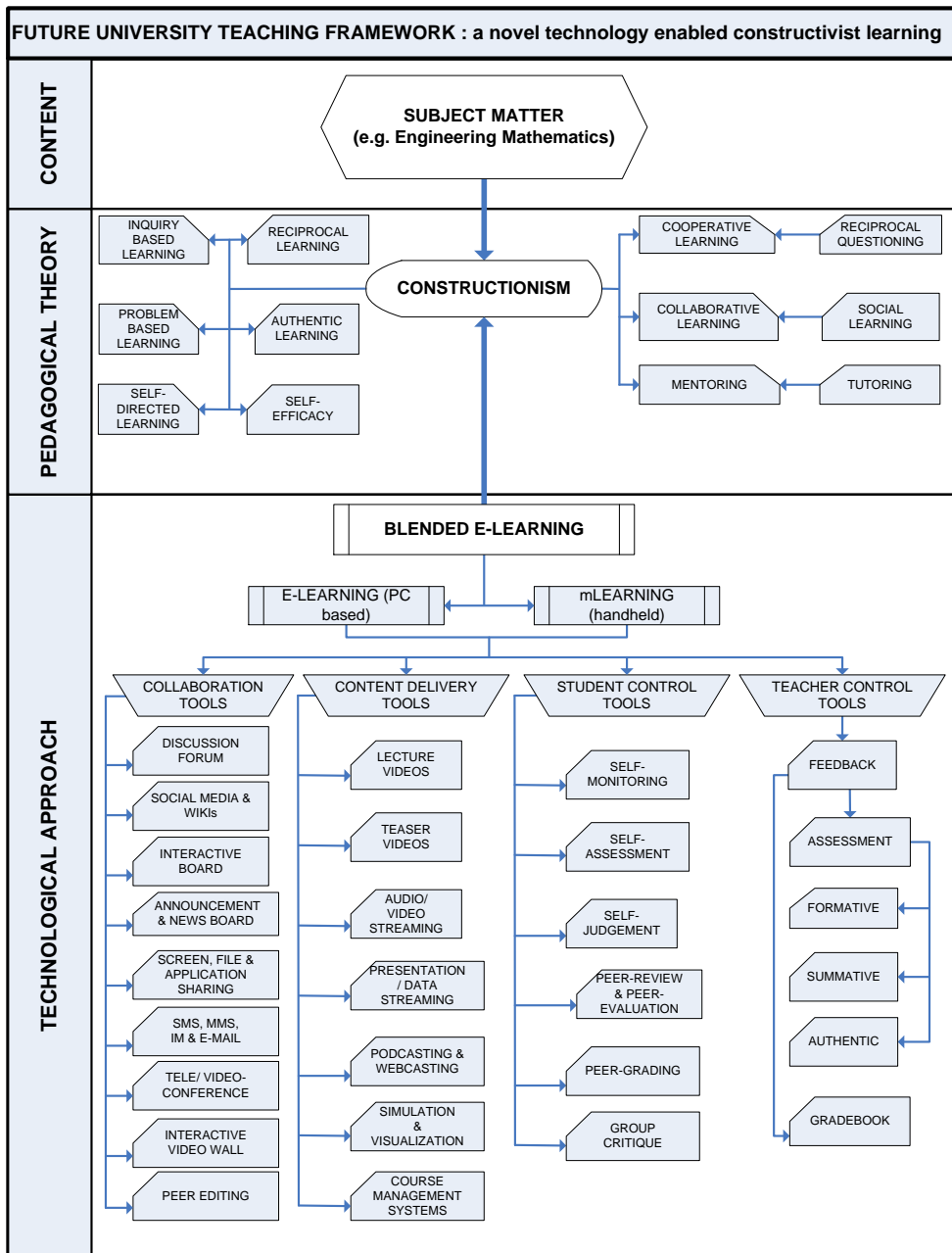
Figure B.1: Future university teaching framework

## IV. CONCLUSION

This paper has presented a critical review of teaching and learning at university level with a focus on future teaching. A future university teaching framework is proposed based on a constructivist theory which promotes active, interactive and collaborative learning. Learners' performance can be improved by applying an appropriate pedagogical theory together with the technological tools presented in this paper. Further work needs to be done to address the discussed technical and pedagogical

B

issues as well as to investigate on the practicality, usability and effectiveness of the proposed approach to future teaching.

## REFERENCES

[1] D. Collins, A. Deck and M. McCrickard, "Computer Aided Instruction: A Study of Student Evaluations and Academic Performance," *Journal of College Teaching & Learning*, Vol. 5, No. 11, pp. 49-58, 2008.

[2] D. Corlett, M. Sharples, S. Bull and T. Chan, "Evaluation of a mobile learning organiser for university students," Journal of Computer Assisted Learning, Vol.21, No.3, pp.162-170, 2005.

[3] P. Devitt and E. Palmer,"Computer-aided learning: an overvalued educational resource?" Medical Education, vol. 33, no.2, pp.136-139, 1999.

[4] A. Dias, J. Carvalho, D. Keegan, G. Kismihok, N. Mileva, J. Nix and T. Rekkedal, "An Introduction to Mobile Learning,"*The role of mobile learning in European education*, 2008. Available online: http://www.ericsson.com/ericsson/corpinfo/programs/ the_role_of_mobile_learning_in_european_education/products/wp/ socrates_wp1_english.pdf Last accessed 30/08/2010.

[5] V. Garaj, "m-Learning in the Education of Multimedia Technologists and Designers at the University Level: A User Requirements Study," *IEEE Trans. on Learning Technologies*, vol. 3, no.1, pp. 24-32, 2010.

[6] J. L. McBrien, P. Jones and R. Cheng, "Virtual Spaces: Employing a Synchronous Online Classroom to Facilitate Student Engagement in Online Learning," *The International Review of Research in Open and Distance Learning*, vol.10, no. 3, 2009. Available from: http://www.eric.ed.gov/PDFS/EJ847763.pdf . Last accessed 29/11/2010.

[7] L.F. Motiwalla ,"Mobile learning: A framework and evaluation," *Computers & Education*, vol. 49, pp.581-596, 2007.

[8] D.H. Schunk ,"Learning Theories - An Educational Perspective," $5^{th}$ edition. Pearson Education Ltd, New Jersey, USA, 2007.

B

[9] B. Stewart, H. M. Hutchins, S. Ezell, D. De Martino and A. Bobba, "Mitigating challenges of using virtual reality in online courses: a case study," *Innovations in Education and Teaching International*, vol. 47, no. 1, pp. 103-113, 2010.

[10] E.T. Welsh, C.R. Wanberg, G. Kenneth and M.J. Simmering,"E-learning: emerging uses, empirical results and future directions," *International Journal of Training and Development*, vol.7, no. 4, pp. 245-258, 2003.

[11] D. Zhang, J.L. Zhao, L. Zhou and J.F. Jr. Nunamaker, "Can E-learning replace classroom learning?" *Communications of the ACM*, vol.47, no. 5, pp.75-79, 2004.

# Appendix C

# Paper II

C

# On the Mobile Technology Enabled Peer-Evaluation: A User Centric Approach

Ghislain Maurice Norbert Isabwe; Martin Carlsen; Halvard Øysæd
and Frank Reichert

University of Agder

E-mails: {maurice.isabwe, halvard.oysad, martin.carlsen, frank.reichert}@uia.no

*Abstract* —In collaborative learning, students at various performance levels work together towards a common goal through both formal and non-formal learning. There is a risk of underperformance for learners unless they can monitor their progress. One solution to cope with underperformance is to allow students to take part in their regular evaluation and feedback by peer-evaluation. Peer-evaluation encourages active participation, and gives the students an opportunity to compare their work to those of others, which leads to positive competition. On the other hand, peer-evaluation gives the teacher an overview of the students' perspectives and expectations from each other which can translate their own understanding of the subject matter. However, peer-evaluation presents many challenges in terms of organization, management, usability and technology support.

This paper discusses how to use the mobile communication technology to support peer-evaluation and proposes a user-centered design approach for system design. Given our interest in mathematics education at university level, we have adopted an exploratory interview study with a target user group consisting of engineering students who have completed at least one mathematics course. Based on the information gathered from the intended users, we propose a mobile peer-evaluation system functional baseline, comprising of processes that are presented in this paper.

*Keywords*—Peer-assessment, peer-evaluation, mobile learning, user-centred design.

## 1. INTRODUCTION

Learning in the $21^{st}$ century comprises of both formal and non-formal learning, the latter being embraced at almost all levels of university education thanks to Information and Communication Technologies (ICT). Learners are struggling to cope with the new ways of learning where the information reaches them in different formats and from different sources. It is difficult to keep track of individual progress in such a learning environment. Further on, the concept of collaborative active learning makes it imperative for learners to cooperate in their learning. Given the differences in students' abilities, there is a need for regular formative assessments to ensure that everyone is on the right track. Topping [16, p.249] argued that "Formative assessment aims to improve learning while it is happening in order to maximize success rather than merely determine success or failure only after the event".

In a collaborative learning environment, students have the possibility to achieve shared meanings of concepts through discussion and argumentation. They have a shared responsibility and ownership of learning; hence they should also play an active role in their progress control. Maclellan [13] stated the need for students to monitor their own performance so that they could effectively use feedback for improvement in learning. Progress control (evaluation) provides performance indicators which can motivate learners to timely achieve their learning goals. Peer-evaluation, a process by which learners evaluate each other, provides feedback to each learner and the process gives them - learners- an exposure to their peers' work. This exposure can create a sense of competition among learners and also help them to experience their peers' approach to problem solving. We also believe that reviewing the work of colleagues through criterion-based reference evaluation does not only promote the generation of a constructive feedback but this also improves the students' reflective learning skills.

Previous studies in the area of technology enabled feedback systems [17][3][14][6] have shown a number of issues such as the difficulty to provide a constructive feedback, inconsistency between teacher's feedback and students' feedback, time consumption, complex facilitation and moderation of peer-evaluation, technical issues in terms of connectivity, usability and others.

The motivation behind this work is the possibility of solving the above mentioned issues, through the use of appropriate information and communication technology tools. This would provide an opportunity to achieve the pedagogical objectives while technological complexities are seamlessly addressed. The question is to know whether the students would be interested in a modern technology based peer-evaluation solution or not, and what would be their needs and requirements for

such a system. This paper proposes a user-centered design approach for a mobile communication technology supported peer-evaluation system.

The aim of this paper is to present the methods and results of interacting with the intended users; in order to find their needs, and establish their requirements for defining the system processes. The mobile communication technology supported peer-evaluation system, which is hereafter referred to as "Mobile peer-evaluation system (MOBIPEV)", entails the use of mobile devices for end-users in the context of "mobile learning" as discussed in section 2.

The next section presents a brief introduction to mobile learning and an overview of existing mobile peer-assessment systems. In the third section, a description of the interview study is given followed by the results findings in section 4. Section 5 discusses the novel mobile peer-evaluation system processes based on the collected users' needs. Concluding remarks and future directions are presented in the final section.

## 2. RELATED WORK

In addition to personal computers, handheld mobile devices are being used for educational purposes, in what is known as "mobile learning". Mobile learning or m-learning offers mobility, portability and availability of learning anytime, anywhere thus making "ubiquitous learning" a reality. It is believed [7] that m-learning will enhance learners' engagement to create, access, revise and share course content. Despite their known limitation in terms of processing power, memory capacity, display screen size and resolution, as well as input facilities, mobiles devices' mobility, availability, affordability and various access network technologies support make them candidates for future educational applications. Several studies have been reported in the literature, mostly focusing on learning content delivery and collaboration using mobile devices [12][1][4].

On the other hand, there is a growing interest of taking mobile learning beyond content delivery and collaboration to include new concepts such as context aware-mobile learning and mobile self/peer-assessment. While the former is out of scope of this work, the latter is closely related to our area of interest. In the following paragraph, this paper summarizes mobile self-assessment and mobile peer-assessment studies of interest.

Liu [11] proposed a peer- and self-assessment model for mobile learning comprising of a step by step list of activities. The model describes the procedures involved to ensure that learning is achieved through multiple assessments. The author raised open questions from the suitability of mobile devices for peer-assessment to

C

procedural arrangements and target user group. Later on, de-Marcos et al. [5] discussed the improvement of student performance in secondary and tertiary education using m-learning auto assessment. The authors presented a mobile web-based tool to support self-assessment in such a way that the students complete questionnaires and the system shows them their results. This solution is limited to multiple choice questions and does not provide elaborate feedback to the student.

Another recent study on mobile self- and peer-assessment [3] has developed a "Mobile Assessment Participation System (MAPS)" on PDA (Personal Digital Assistant) platform. Using this system, students provide feedback on their peers' presentations; and subsequently each student can assess his or her own presentation as well as the peers' presentations anonymously via PDA. This approach shows potential benefits to the students, as they receive detailed feedback based on predefined assessment criteria. The author stressed the need to prevent potential negative effects of unfair or harsh peer-assessment from those students with low scores; it was suggested that all results be given once the entire process is finished. It is noted that this system was designed only for assessment of presentations, which means that there is no record for student's work; therefore students may challenge their given scores and it may also be difficult for students to recall how they performed in order to improve their performance in the future. Furthermore, the system does not provide for asynchronous assessments and from a system design perspective, there is lack of user involvement even though it is vital to consider user requirements from intended system users.

## 3. METHODOLOGICAL APPROACH: USER CENTRED DESIGN

### *3.1. Methodology consideration and selection of tools*

This research work has adopted an interview study because of two main reasons: a pedagogical perspective and best practice in user centered design (with reference to ISO 13407 [9]). The first reason, the pedagogical perspective, stems from the fact that interviews enable the interviewer to collect the learners' opinions about peer-evaluation as a process, especially on those aspects relating to how this can affect either positively or negatively the teaching and learning. By conducting interviews, an understanding of what learners would expect from the peer-evaluation process is depicted, including the learners' views on how and when this should be undertaken. Furthermore, any misunderstanding or misconceptions would be timely cleared for both the interviewee and the interviewer throughout the interview process, which also serves as a learning opportunity for both. The second reason is that, an interview study can be used as part of an iterative development cycle for the development

of human-centered interactive systems. The interviews foster active involvement of users in understanding and specification of the context of use, user requirements as well as organizational requirements. Further on, usability issues have to be considered in software product development process, in order to develop easy to use applications which can meet the intended users' needs.

This research has considered one-to-one interviews with students, whereby the same researcher conducted interview sessions with digital audio and video recording. Although digital audio and video recording presents many benefits in terms of storage, sharing, processing and analysis; one of the interviewees was not comfortable with video recording, thus opting for audio recording only. With reference to the works of Hall [8] and Roschelle [15], Carlsen [2, p.58] reiterated the effects of video camera presence in data collection, saying that "the key question is whether the participants change their behavior, because of the video camera, to a degree that makes answering of the research questions difficult". Besides dealing with video recording issues, this research has also considered other ethical issues including but not limited to participants' privacy, anonymity, the consent to participate, the right to withdraw from the research, data usage and honesty on behalf of the researcher among other things.

In order to obtain a representative sample of users, this study identified and selected a target group of engineering students who have completed at least one mathematics course at undergraduate level and a graduate (master) student who has taken an advanced mathematics course. With reference to the study by Kujala and Kauppinen [10] regarding the number of representative users, we consider that ten users can provide useful information given the scope of our study. Students meeting the above mentioned criteria were randomly contacted both in person and by e-mail. The areas of study of the student participants comprise of Computer Engineering (7 students), Civil Engineering (1 student) and Renewable Energy (2 students). There were 9 undergraduate students and 1 master student. The age group was 20-25 years old (7participants) and 25-30 years old (3 participants). Two female participants and 8 male participants were interviewed on a one-to-one basis, each interview taking roughly 25 minutes, and all interviews were conducted during a 2 weeks period.

### 3.2. Interview questions

The interview questions used in this study are framed under three main themes as shown below:

1. Students' opinions regarding "peer-evaluation" process:

C

(a) On a scale of 5, how would you rate peer-evaluation with 5 being "Strongly like it" and 1 being "Strongly dislike it"?

(b) What would be your preferred type of feedback? Please choose from the list below and give details:

    i. Peer-feedback

    ii. Teacher feedback (formal feedback)

    iii. Automated (computer generated) feedback

(c) Learners participation in peer-evaluation:

    i. Would you take part in peer-evaluation as a feedback provider? Please give details

    ii. If you answered yes on the previous question:

        A. How many peers' work would you feel comfortable to evaluate?

        B. How many evaluation cycles (iterations) are you willing to make?

        C. How frequently are you willing to take part in peer-evaluation?

    iii. How long should a peer-evaluation session take?

    iv. How much of your own free time are you willing to spend on peer-evaluation?

    v. Would you like to receive feedback from your peers? Please provide details.

    vi. What is your opinion regarding anonymity for feedback provision?

(d) The expected impact of "peer-evaluation" on teaching and learning:

    i. How do you think peer-evaluation could influence your learning performance?

    ii. Would you like peer-evaluation to contribute to the final grade?

        A. Do you prefer group work or individual work?

        B. What do you think should the ideal group size be?

        C. What do you think should be the grouping criteria?

    iii. Feedback on feedback:

        A. Do you think there should be an evaluation (by a learner) on the feedback provided by another learner? Please provide reasons.

        B. Should the feedback on feedback contribute to the final grade?

(e) Opinion on mobile peer-evaluation system (MOBIPEV)

    i. Would you prefer MOBIPEV over a personal computer web based peer-evaluation? Why?

    ii. What would you prefer between synchronous peer-evaluation and asynchronous peer-evaluation? Please give details.

    iii. Considering a MOBIPEV intended for a mathematics course, please give your opinions about the following:

      A. Minimum acceptable screen size

      B. Graphics / Visualizations: minimum screen resolution, colors

      C. Input type: QUERTY keyboard, numeric keypad, touch screen with/without radio buttons, drop-down menus

      D. Access technology: Wi-Fi, 3/4G, Bluetooth

      E. Multimedia support: Audio, video, still pictures

### 4. INTERVIEW STUDY RESULTS AND ANALYSIS

In this study, we adopt a thematic and comparative analysis in order to present the outcomes of the interview study.Where possible a graphical representation of data is given together with interpretations, otherwise a summative discussion of the respondents' points of view is provided.

### *4.1. Students' opinions regarding "peer-evaluation" process*

The interview' results indicate that the students are interested in getting feedback from peers, the reasons being that students can easily remember things if they do it many times through peer-evaluation and can improve their performance if regular feedback is given. Student number five said that "it can be easier to improve if you get feedback more often". Additionally, students could learn while marking others' works. However, one of the respondents was concerned with the ability of students to evaluate their peers' works.

On the other hand, there are clear indications that students would prefer the teacher's feedback because they believe that the teacher knows better even though the peer-feedback would be more time saving. Therefore, the peer-evaluation process should be well explained to students and the grading criteria must be clearly and objectively presented. Figure C.1 shows the students' attitude regarding MO-BIPEV. "Std#" represents a student number hereafter.

Furthermore, it is shown in Figure C.2 that, according to the students, the number of feedbacks/assessments should be around 3-4. The respondents were con-

C

Rating of MOBIPEV (5-strongly like it, 4-like it, 3-undecided, 2-dislike it, 1-strongly dislike it)
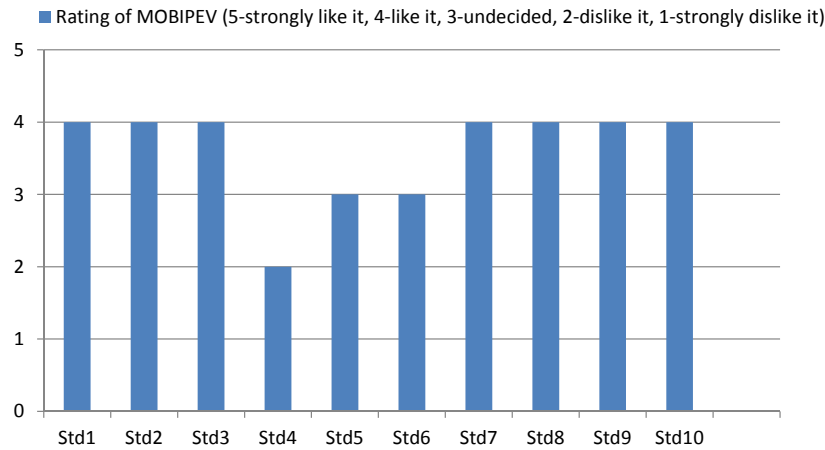
Figure C.1: Rating of MOBIPEV

cerned about the amount of time spent on peer-evaluation but they also stressed the importance of having multiple feedbacks. It was mentioned that students could learn various approaches to problem solving and get better understanding of the course subject by reading feedbacks from different individuals.

Figure C.3 and Figure C.4 respectively show that, the amount of effort for peer-

Number of peers' works assessed by one student
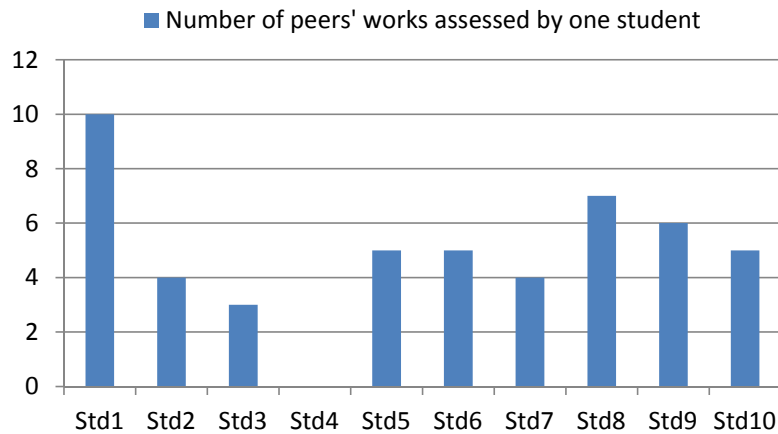
Figure C.2: Peers' works assessed by a student

feedback should be within limits of 1 hour and peer-evaluation should be included in a course not more than every 2-3 weeks.

Another finding was that the iterations in peer-evaluation are useful but should not be more than two. Iterations could be used to increase learners' mastery of the subject through repeated tests on a given topic. However, if a particular group of students does not perform well despite the iterations, the group members should be swapped with members of other groups.
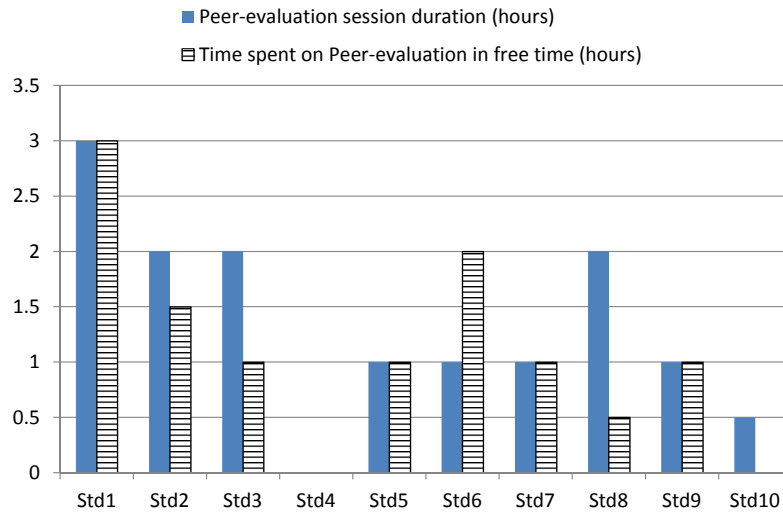
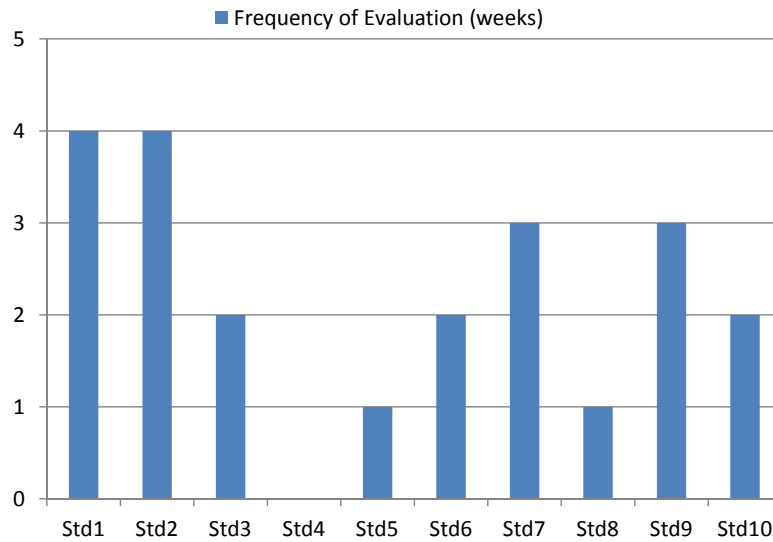Figure C.3: Peer-evaluation duration time



Figure C.4: Frequency of evaluation

On the issue of anonymity in peer-evaluation, 50% of the respondents said that it should be compulsory, 40% of them thought that it is not necessary; with student number 7 explaining that "it should be open so that you can have the possibility to ask the one that marked you why, may be he can explain why and may be help you". One student was indifferent on this.

### 4.2. The expected impact of "peer-evaluation" on teaching and learning

This research has found that the students expect the peer-evaluation to have a positive impact on their learning performance. It was said that peer-feedback could give more opinions in a short time and by seeing the peers' work, students would push themselves to work harder in order to get better results. In addition to this positive competition effect, the respondents revealed that peer-evaluation would improve their analytical skills as they try to provide a constructive feedback.

As for the contribution of peer-evaluation results to the final grade, 60% of the
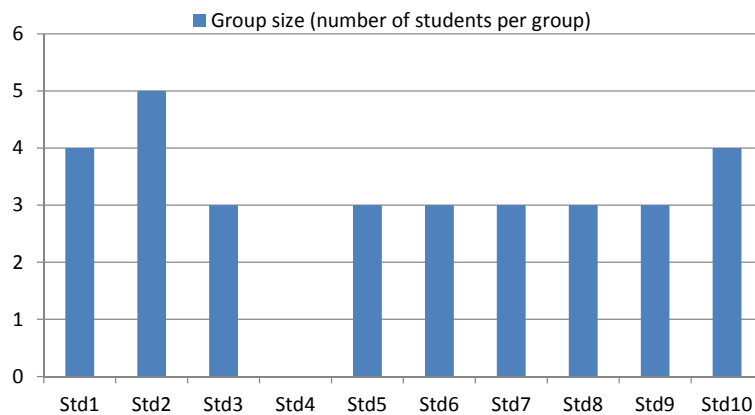


Figure C.5: Student group size

respondents thought that this would not be helpful because they don't trust that their peers' evaluation would be correct and fair. Student number 3 said that "it would have to be marked by at least 4-5 people, I think, for that to really work and to be fair, so that not just one get graded and you are stuck with that grade". Another raised concern was that the final grade could be affected by underperformance at the early peer-evaluations when the students have not yet settled into the course. On the other hand, 40% of the respondents said that peer-evaluation results should contribute a percentage of the final grades, with one of them suggesting up to 70%.

Figure C.5 indicates that when students study in a group, there should be not more than 3 students per group. The respondents suggested a manageable size of 3 for all group members to be able to discuss without much interference or the tendency to move away from their task. This size also allows easy communication and it is expected that at least one group member is likely to know how to approach the given assignment. It became apparent that the group members' selection criteria were not straightforward, but it was suggested that groups be made of a mixture of different skills/performance levels perhaps based on earlier grades. Even though

there were also suggestions of putting together the students of the same caliber, ideally each group should consist of at least one very good student, one good student and one average or below average student.

When asked whether a "feedback on feedback" should be provided, respondents indicated the need for it, saying that it would help on quality feedback provision. But, this being time consuming, they also suggested that it should not be carried out all the times. An indication of 1 out of 4 feedbacks was given. 60% of the respondents recommended the contribution of the feedback on feedback towards the final grade to ensure commitment and objectivity in feedback provision. One participant noted that this contribution should not exceed 5% of the final grade, whereas two other participants commented on its drawbacks such as time consumption and penalizing students on first rounds of peer-evaluation when they are not yet confident about the process itself and the course of study.

### 4.3. Opinion on mobile peer-evaluation system (MOBIPEV)

The participants were also asked questions designed to evaluate their attitude about a potential mobile communication technology supported peer-evaluation system, which could be used in mathematics courses. The respondents indicated a great interest in the system but 60% of them mentioned their preference for a Laptop PC over smaller mobile devices. This is also reflected in Figure C.6 which shows the minimum acceptable screen size for the mobile devices. For instance, student number 1 indicated that the minimum screen size should be 3 inches because "it is the same screen I've been using to read text and I can read documents on this". In addition to that, 90% of the respondents chose QUERTY keyboard as their preferred input device for text input in feedback provision. On the visualizations and screen resolutions, the respondents appeared not to be aware of available options but they noted the need for color graphics.

Furthermore, all respondents indicated their concern about data traffic costs, thus opting for Wi-Fi access technology because it is free to use on university campus and cheaper than cellular network if not on campus. Only 10% of the respondents expressed a willingness to pay data traffic charges to carry out peer-evaluation, but not to exceed 30 minutes of cellular network connection time. It is noted that, 60% of the respondents preferred "asynchronous" peer-evaluation because of flexibility. The advantages of synchronous peer-evaluation such as easier organization and efficiency were noted by 20% of the participants. The participants also indicated that written text feedback is more suitable because the reader can have direct control and easily grasp the feedback. Audio feedback would be optional.
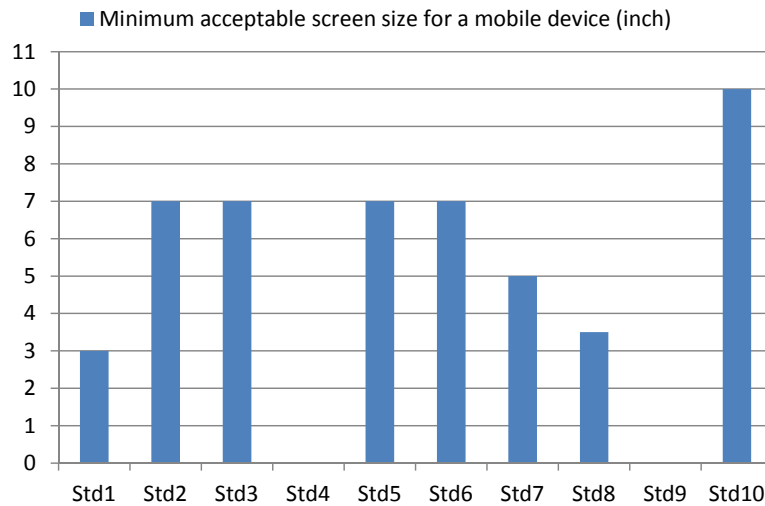
Figure C.6: Minimum acceptable screen size (inch)

## 5. A Novel Mobile Peer-evaluation System Processes

The previous two sections describe user studies and analysis that are used for studying the user requirements and context of use. Subsequently, we proceed with a conceptual presentation of the MOBIPEV system processes as follows:

1. The students enroll for a course

2. The students learn the course contents

3. The system prepares exercises

4. The system creates student groups (criteria based grouping)

5. The system distributes group exercises

6. Groups meet physically to work on exercises

7. Group members separately submit individual exercise solutions

8. The system assigns answer-sheets for review/evaluation to students

   (a) Students are selected for evaluation and feedback provision:

      i. random selection
      ii. criterion based selection

(b) Each student is assigned 3 answer-sheets

9. The system distributes answer-sheets and correct solutions to students

10. Students evaluate answers and submit their feedback and grades according to:

    (a) The review/feedback criteria set by the teacher

    (b) Grading criteria set by the teacher

11. The system has now three reviews per answer sheet:

    (a) The quality of review is ensured by: Feedback on feedback with reference to the correct answer

    (b) Comparing the reviews from 3 students

12. System generates and distributes new exercises based on last exercises' topic

13. Students meet physically and work on updated exercises

14. Go to step number 7 one more time

15. Post processing:

    (a) Performance statistics are collected

    (b) Individual progress monitoring and reporting

## 6. CONCLUSIONS AND FUTURE WORK

A user-centered design approach was adopted to develop mobile peer-evaluation system processes. The results of one to one interviews of the potential system's users, have given early indications that the students are interested in getting feedback from peers. The regular peer-feedbacks should be carried out every 2 to 3 weeks; with each session not taking more than 1 hour, during which every student participant would provide 3-4 feedbacks.

The respondents commented on the positive impact of peer-feedback on learning performance and they indicated the necessity to implement the system on mobile platforms with screen sizes of 7" to 10" as well as QUERTY keyboard text input facility.

Future work will follow the steps of an iterative user-centered design cycle to develop the MOBIPEV system. The next step is the visualization of the design ideas and evaluation of designs against user requirements through user studies. This research has encountered user involvement challenges; however student participants

took part thanks to using multiple communications channels. The authors will in the future engage with the intended users at a very early stage.

### REFERENCES

[1] G. Botzer, M. Yerushalmy, "Mobile application for mobile learning", in *Proceedings of IADIS International Conference on Cognition and Exploratory Learning in Digital Age*, Algarve, Portugal, December 2007, pp. 313-316.

[2] M. Carlsen, "Appropriating Mathematical tools through problem solving in collaborative small-group settings", *PhD Thesis*, University of Agder, pp. 58-59, 2008.

[3] C. Chen, "The implementation and evaluation of a mobile self- and peer-assessment system", *Computers & Education*, vol. 55, no. 1, pp.229-236, 2010.

[4] R. Cobcroft, "Literature Review into Mobile Learning in the University Context",*Queensland University of Technology*, 2006. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.93.2617& rep=rep1&type=pdf. Last accessed 24/2/2011.

[5] L. de-Marcos, J. R. Hilera, R. Barchino, L. Jiménez, J. J. Martínez, J. A. Gutiérrez, J. M. Gutiérrez and S. Otón,"An experiment for improving students performance in secondary and tertiary education by means of m-learning auto-assessment", *Computers & Education*, vol. 55, no. 3, pp.1069-1079, 2010.

[6] P. Denton , J. Madden, M. Roberts and P. Rowe, "Students' response to traditional and computer-assisted formative feedback: A comparative case study", *British Journal of Educational Technology*, vol.39, no.3, pp. 486-500, 2008.

[7] A. Dias, J. Carvalho, D. Keegan, G. Kismihok, N. Mileva, J. Nix and T. Rekkedal, "An Introduction to Mobile Learning",*The role of mobile learning in European education*, 2008. Available online: http://www.ericsson.com/ericsson/corpinfo/programs/

the_role_of_mobile_learning_in_european_education/products/wp/
socrates_wp1_english.pdf Last accessed 30/08/2010.

[8] R. Hall,"Videorecording as theory", in *Handbook of research design in mathematics and science education*, A.E.Kelly and R.A. Lesh, Eds. Lawrence Erlbaum, Mahwah, NJ, USA, 647-664, 2000.

[9] ISO, "ISO 13407 Human Centred Design for Interactive Systems". International Organization for Standardization, Geneva, Switzerland, 1999.

[10] S. Kujala and M. Kauppinen, "Identifying and selecting users for user-centered design", in *Proceedings of the 3$^{rd}$ Nordic Conference on Human Computer Interaction*, Oslo, Norway, October 2006.

[11] E. Z. F. Liu,"Peer and Self Assessment for Mobile Learning", in *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Lugano, Switzerland 2004, L. Cantoni & C. MCloughlin (Eds.), Chesapeake, VA, USA, pp. 4370-4372.

[12] G. Liu and Z. Jiao, "The design of mobile learning system for teachers' further education", in *Proceedings of the 2nd International Workshop on Education Technology and Computer Science*, Wuhan, China, March 2010.

[13] E. Maclellan, "Assessment for learning: the differing perceptions of tutors and students", *Assessment & Evaluation in Higher Education*, vol.26, no. 4, pp. 307-318. 2001.

[14] J. Mcluckie and K. J. Topping, "Transferable skills for online peer learning", *Assessment & Evaluation in Higher Education*, vol. 29, pp.563-584. 2004.

[15] J. Roschelle, "Choosing and using of video equipment for data collection", In *Handbook of research design in mathematics and science education*, A. E. Kelly and R. A. Lesh, Eds. Lawrence Erlbaum, Mahwah, NJ, pp. 709-729. 2000

[16] K. Topping, "Peer Assessment between Students in Colleges and Universities", *Review of Educational Research*, vol. 68, no. 3, pp.249-276. 1998.

[17] V. Venkataramanujam and P. Laroche, "Panther Peer: A web-based tool for peer evaluation", In *Proceedings of Florida Conference on Recent Advances in Robotics*, Jacksonville, FL, May 2010.

# Appendix D

# Paper III

D

# Towards Integrating Technology Supported Peer-to-peer Assessments into Mathematics Education:
# Experiences with iPad Mobile Tablet Technology

D

Ghislain Maurice Norbert Isabwe, Frank Reichert and Svein Olav Nyberg

Faculty of Engineering and Science, University of Agder

Jon Lilletuns vei 9, 4879 Grimstad, Norway

E-mails: {maurice.isabwe, frank.reichert, svein.o.nyberg}@uia.no

*Abstract*—**This paper addresses technology supported formative assessment in university mathematics education. The challenges of formative assessment are the requirements for regular feedback and more student engagement in the learning process. This paper suggests integrating peer-to-peer assessment in mathematics education, using mobile tablet technology. The students are engaged in providing feedback to each other and the technology allows for fast and regular feedback provision. The paper presents the results of experiments with undergraduate engineering students, using iPad tablets and a learning management system. It is shown that mobile tablet technology can greatly contribute to the integration of peer-to-peer assessment into mathematics education; and providing peer-feedback is a practical approach to formative assessment.**

*Keywords*—Peer-Assessment, mobile technology, formative assessment.

## 1. INTRODUCTION

The new media technologies have not only extended learning opportunities, but they are also reshaping the university education as a whole. The ever increasing number of students and the quest for excellence in education, are also driving research efforts into new pedagogical models, which would be appropriate in this media-rich world. For instance, all undergraduate engineering students must study mathematics courses; and they may be grouped into larger classes with a minimum of teacher-to-student interaction (this is a real concern at the University of Agder and other universities around the globe). Technologies such as real-time video streaming are being used for teaching, but there is still a challenge to assess the students' progress as they learn (formative assessment).

The main purpose of this study is to investigate the students' attitudes towards technology enabled peer-to-peer assessment (P2PASS) using iPad tablet computers. P2PASS is a form of formative assessment, expected to have a positive impact on the students' learning performance as well as their reflective skills. Peer assessment encourages active learning and collaboration among students, as they assess each other's work and provide constructive feedback. On the other hand, this study will provide empirical data on the usability of the adopted mobile technology and the feasibility of P2PASS in a mathematics course.
The study will address the following research questions:

- What are the benefits that students can get from involvement into a P2PASS in mathematics education at university level?

- What are the challenges and opportunities for integrating mobile technology enabled P2PASS in mathematics education at university level?

The authors argue that mobile tablet technology offers many advantages for learning: students can experience a natural feel with finger writing or stylus in the same way as pen and paper; this would foster a faster technology adoption. Once the students get used to this technology, it can also be time saving compared to using alternative equation editor tools such as MathML (Mathematics Markup Language), which requires a substantial amount of time to input mathematical symbols. There is also a lack of flexibility in automated systems for the student to show his own approach to problem solving. Grading systems rely mostly on multiple choice questions (MCQ) type, hence missing the possibility to assess the student's understanding, strategies, reasoning, procedures and communication because those aspects cannot simply be reflected in the final answer. Moreover, peer-assessment on tablet technology adds a great advantage to be able to provide feedback on the

same sheet as the assignment itself (student's work).

The remainder of this paper is organised into 4 sections. In Section 2, this paper provides a brief overview of peer-assessment, including technology supported peer-assessment systems. In Section 3, the methods for this study are presented and in Section 4, the results of the experimental work are presented together with analysis. The final part, Section 5, summarizes our conclusions and future directions.

## 2. RELATED WORK

Peer-to-peer assessment stems from the practice of active learning. Falchikov [7] emphasised the importance of students' involvement in the assessment process not only as the "testees" but also as the assessors. The author suggested that students could be involved more productively in their assessment by peer assessment. In peer assessment, students rate the performance of their peers through a four-stage process comprising the preparation, the implementation, the follow-up and evaluation as well as the replication. Despite peer-assessment being an "excellent way of enhancing the learning process", it may have some issues such as the students' lack of confidence and capacity to assess fairly and accurately, and their unwillingness to do the teacher's job among other things.

In recent studies on technology-supported peer assessment systems [12, 1, 3, 5], several advantages were reported, from the savings in time and costs to improved students' performance. Web-based peer-assessment systems allow the assessors (students and teachers) to enter grades and feedback. The systems described may be efficient for subjects such as history, language studies and other studies for which students are assessed on oral presentations or plain text answers. The authors have not reported on any tools for writing mathematical symbols and equations. In addition to that, there are no indications of how the assessors could clearly indicate on the same sheet any missing points and provide easy access to feedback. It is noted that mobile technology has also been considered for peer-assessment [3, 5], but in both studies there was no consideration for a touch input interface. A separate study at the University of Southern Queensland [2] considered the courses where standardized answers and feedback could not be generated, thus requiring a marker's feedback on the individual level. Such courses involve a lot of mathematical or technical drawings, which proved to be time consuming for students to produce feedback. In that work, they studied the online marking with typed comments (there were text boxes used for adding comments on each assessment criteria) and a second option to provide hand written annotations on the students' assignments using a Tablet PC (Toshiba Portege M750). At the end, the marker in this experiment

was "supportive of the use of the Tablet PC". The analysis done thereafter showed no significant difference in the quantity and the quality of feedback, but still the handwritten feedback provided more details.

Besides special tools that are needed for assessing mathematics, there is also a need for appropriate mathematics assessment rubric to help students objectively assess their peers' work. Egodawatte [6] proposed a comprehensive rubric for assessing mathematical problem solving tasks.

## 3. METHODS

Subsequent to a literature review, an experimentalist approach was adopted for conducting user studies and technology evaluation. The investigations consisted of experiments, observations and a survey which was completed at the end of the experiments. To study the integration of P2PASS into mathematics education, the researcher obtained consent from the teaching staff of first year and second year engineering mathematics to use the exercises from their respective courses. This has allowed the study on the assessment of learning while it is happening. The teachers provided both the question papers as well as the correct answers, the latter being needed for the students to provide correct and meaningful feedback to each other.

### 3.1 Research intentions

The practice of peer assessment has been around for several years and in different fields of study. However, to the best of our knowledge, still a lot has to be done in the area of mathematics peer-assessment based on mobile tablet technology. Therefore, this study intends to help understand this topic from a practical point of view:

1. Can students perform the peer assessment in mathematics using mobile technology tools and the LMS?

2. How do students actually perform the involved tasks (solving mathematics problems, providing and receiving feedback)? Which usability problems that the students may find?

3. How is the student peer-feedback? Questions related to the quantity, quality and clarity of the peer-feedback

### *3.2 Participants sample*

The participants in this study are engineering students in: mechatronics, as well as civil, computing, electrical and electronics engineering. All participants were taking a mathematics course at the time of experiments and, they had basic computer literacy without prior experience of using iPad tablets. There were 96% (23)male and 4% (1) female students. 63% of the participants were between 20-25 years old, whereas 17% (4) were below 20 years and the remaininng were above 25 years old including 13% (3) older than 30 years. With a total of 24 respondents, the study would uncover usability problems to a great extent. In fact, previous studies [9] [10] suggest that as few as 5 users are good enough for simple user testing (qualitative studies) and 20 users can typically provide a reasonable confidence interval in quantitative studies.

The experiments were conducted during the autumn semester 2011. This paper reports on the researchers' observations, the participants' opinions collected through a think-aloud technique and the results of a survey instrument.

### *3.3 Systems and technologies*

This study was based on the use of Apple iPad tablet computers with a selection of mobile applications for the iOS operating system. The iPad was chosen as a mobile platform to take advantage of the mobility, portability, wireless connectivity, relatively high processing power as well as a large memory. Additionally, the iPad has a good support for multimodal user interfaces including the support for handwriting. The iPad touch screen is of a great interest because it is possible to directly write on it, especially the mathematics which involve a lot of symbol characters in equations and formulas.

In this work, we used a mobile application to annotate, delete, and input text on top of PDF documents, using either a finger or a stylus pen.

It is argued that for a formative assessment to be effective, the feedback should be timely accessible to the intended receiver (a student). On the other hand, however, peer-to-peer assessment also requires equal active participation of all students, both as feedback providers and feedback receivers. Therefore, there is a need for a system to allow submission of the work to be assessed and subsequent access to the same work for the assessors (feedback providers); especially in case of a synchronous assessment process. This was achieved using a Learning management System (LMS) called "Fronter" [11] and an iPad web browser application "iCab-
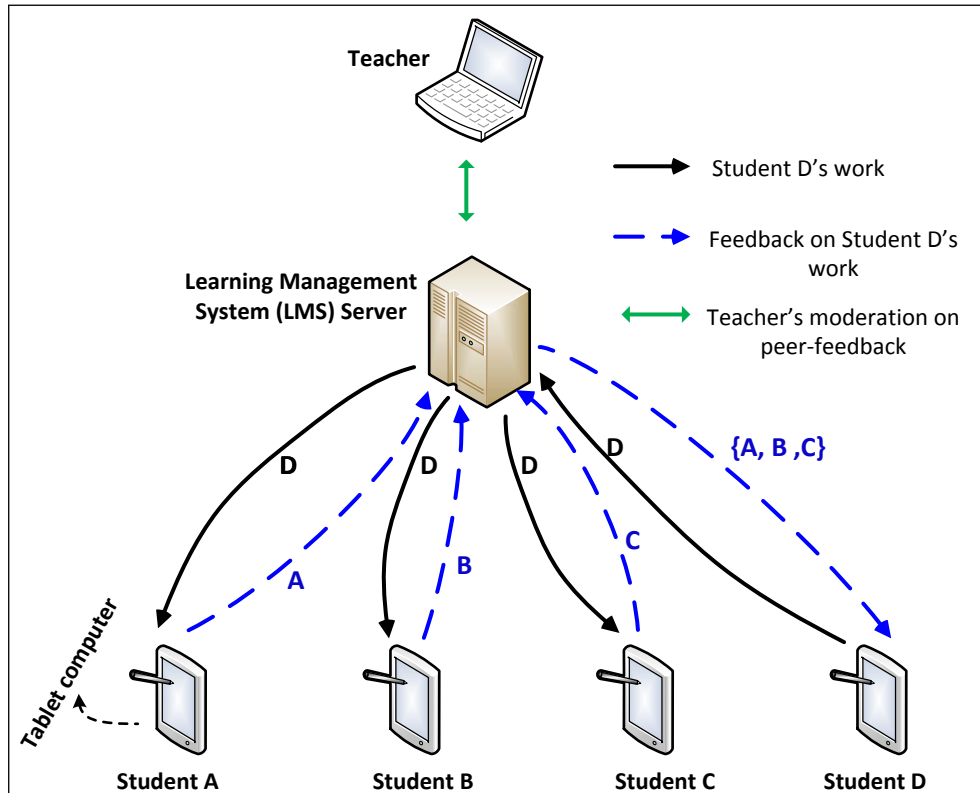
Figure D.1: Peer-to-peer assessment experimental model

Mobile" [4] which supports downloading and uploading of files to the LMS. Each participant can have read and write access rights to documents owned by three other students so that he/she could assess their work as illustrated in Figure D.1. In this way, everyone was able to provide feedback to up to three other students, and likewise receive up to three feedback from different colleagues. It is argued that this can help students to learn from different perspectives.

### *3.4 Experiment design*

This study was conducted in a controlled environment, a laboratory setting as shown in Figure D.2. Before the experiments begin, the researcher uploaded to the LMS a set of mathematics exercises provided by the teacher. At the start, each student was given an iPad, and the researcher explained the peer-to-peer assessment process for 10 minutes, with a brief demo of the tools on the iPad. Then students were grouped according to their performance in the last mathematics exams, in such a way that each group of 3 students would have at least one member with either an "A" or "B" grade where possible. Collaboration was encouraged among group members. Upon completion of the given exercises, the correct answers were up-

loaded to the LMS, and the research explained the mathematics assessment rubric, which consisted of five criteria: the Understanding, Strategies, Reasoning, Procedures and Communication. The assessors (students) were required to rate their peers' performance (High, Medium, Low) and provide a feedback. Once all the papers are marked and uploaded back to the LMS, each participant should be able to see his/her initially submitted work along with the feedback.



Figure D.2: Peer-to-peer assessment session

Subsequent to students' grouping, each participant solved the given questions using the iPad and submitted the work to the LMS. Once everyone has submitted, the correct answer sheet was made accessible to all, and every participant was assigned 2-3 papers to assess with reference to the assessment rubric. The next step was to submit the marked papers with feedback to the LMS so that each participant could have access to 2 or 3 feedback provided by his/her colleagues (peers).

A survey instrument was used to collect students' opinions on peer-to-peer assessment in general, their experience with mobile technology supported peer-to-peer assessment system and the way forward (potential improvements).

## 4. Results and Analysis

### *4.1 Summary of the researcher's observations*

At the beginning of all experiments, students appeared very interested in the process and as expected some of them started exploring the iPad as soon as they were handed to them. There was a mixture of curiosity and a great interest in the new experience. As the researcher explained about the process, students were engaged in finding out the available tools on iPad and within 5-10 min, about 40% of them had already managed to download the mathematics question paper. It was also observed that around 25 % of the students had a tendency to first solve the problems on paper then write down the answers on the iPad.

(a) Student 'A' receives feedback from student 'Y'.

(b) Student 'A' receives feedback from student 'Z'.

Figure D.3: Example of 2 feedback received by one student.

Despite the guidance of the researcher for the students to work on the touch interface straight away, still some of them resisted and kept on using both methods (pen and paper as well as iPad touch interface). 60 to 70 % of the students used

the pen at least on one occasion for solving the math problems, and one of the respondents just solved all the problems on paper and the researcher helped to scan the paper (using the iPad camera) and uploaded the paper as a PDF document on Fronter. On the other hand, all students were very enthusiastic in providing peer-feedback using the touch interface. Figure D.3(a) and Figure D.3(b) illustrate an example of how two students provided feedback on the same work but in a different way, with one marker providing an indication of what was missing and the right formula that should have been used.

(a) Detailed feedback.
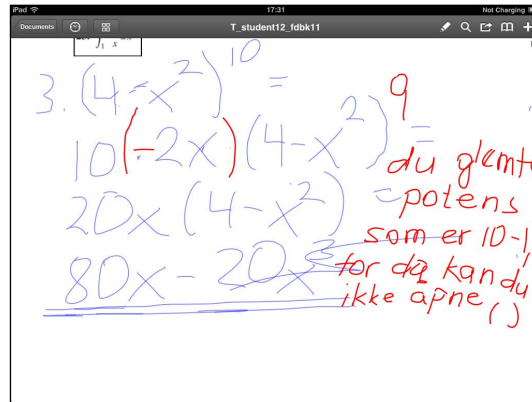


(b) Summary feedback.
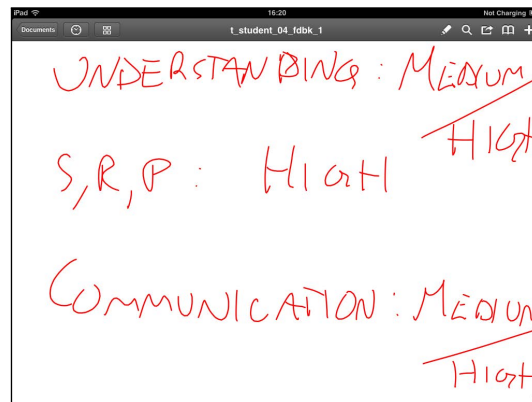


Figure D.4: Peer-feedback provision.

Peer-feedback comprised of both free text as well as typed text. Even tough an assessment rubric was given, many students also gave a feedback in their own words and indicated the errors on the answer sheet as shown in Figure D.4(a). On the other hand, however, there were also students who used keywords for the performance levels (Low, Medium, High) to rate their peers' work as shown in Figure D.4(b). Annotations were observed on a majority of marked paper; which indicates the willingness of students to provide a more personalized feedback rather

than strictly conforming to the assessment rubric. This study showed indications of promoting student responsibility and high level of engagement in learning.

Collaboration among students was also stressed in this study, and students were often seen seeking help from the peers in their group as well as those in the neighbouring group. Timely help was offered as the researcher observed the students explaining the math principles and referring their peers to the relevant course materials from their mathematics books.

From the usability perspective, all participants were generally challenged by the new tools and needed assistance from the researcher, in addition to the instructions sheet that was handed to them at the beginning. The user interfaces were not very intuitive, therefore there was a higher necessity to recall rather than recognise, which usually minimise memory loading on behalf of the user. System message boxes such as "Open In" or "Save in Downloads" don't tell much the user unless he/she is quite familiar with the interface. The learnability of the tools proved difficult.

The affordance of the "PDF Expert" application was liked by the majority of users because they could easily manage to choose the tools needed for opening a file, writing and saving; but scrolling and clicking was not obvious since the system responsiveness was not always the same. Students adopted a trial and error approach to achieve their goals. The students appeared to have the pleasure with the iPad, and the portability of the device was well appreciated with some users sitting in a very relaxing way while working on the given task.

### *4.2 Survey results*

### *4.2.1 Students' opinions on P2PASS*

In a previous study related to student peer-assessment [8], we have found that students would be interested in getting feedback from their peers. The survey results in this study confirmed a positive attitude towards peer-assessment, with only 8% of the participants below the average on the Likert scale as shown in Figure D.5(a). The majority of the respondents (67%) believe that their colleagues can provide them with a meaningful and fair feedback. In addition to that, 50% of the respondents felt confident to make a fair and responsible assessment of their peers' work and 25% were not sure, whereas 25% of the respondents said 'no'. Upon completion of the peer to peer assessment exercise, 21% and 38% found the peer feedback 'very useful' and 'useful' respectively.

(a) P2PA rating scale.

(b) Usefulness of P2PA.

(c) Confident to provide feedback.
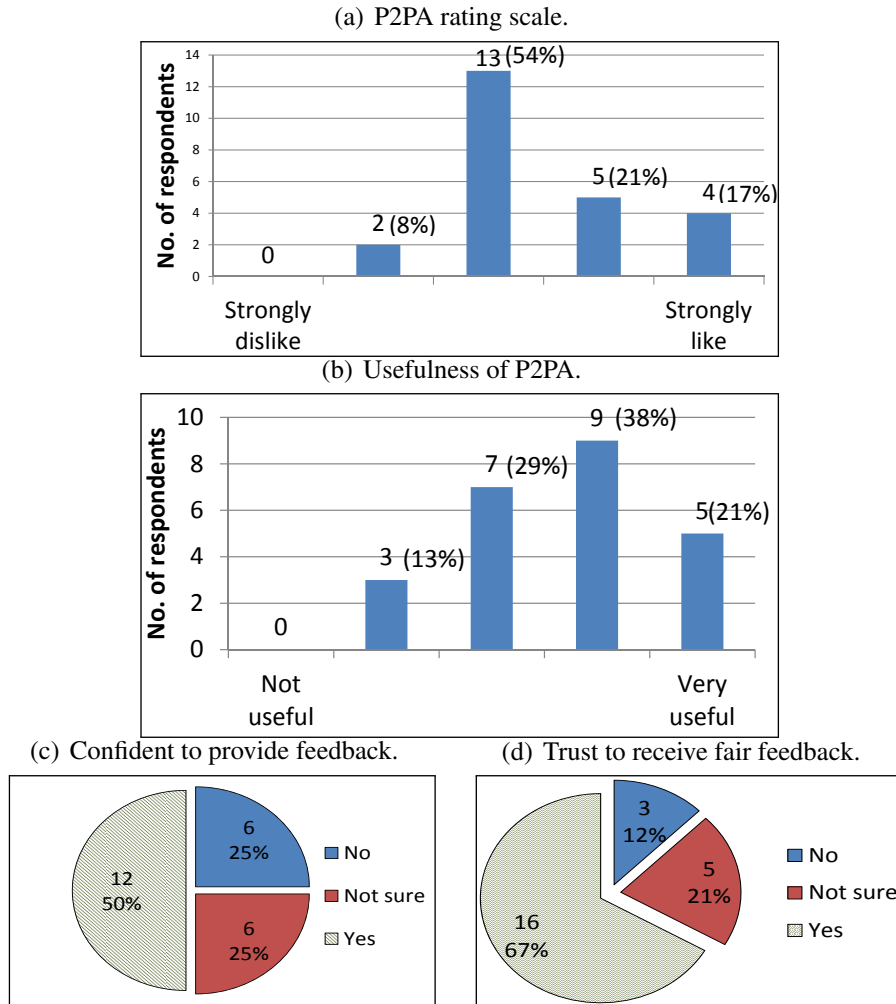
(d) Trust to receive fair feedback.

Figure D.5: Students' opinions on P2PASS process.

The participants also mentioned the usefulness of peer-feedback provision, with statements such as "it could help me understand if i did see what other people do", "getting to see common errors would be useful for me too" and "when I have to explain something to another person I do understand it better myself". Peer-feedback provision also helps in reflective skills development as one student pointed out: "Helping others to understand is an easy way of forcing myself to reflect on my own competence". Other students were interested in peer-feedback because they believe that peer-feedback on assignments greatly helps a student's progress in his/ her learning process. The study suggests that 20-40 minutes could be spent on feedback provision regularly (at least once every two weeks).

On the other hand however, solving the mathematics problems on iPad appeared time consuming for the participants since it was their first time using this tool. The user interfaces were not user friendly, and one of the student expressed his frustra-

tion saying that 'A lot of time was wasted due to problems with the interface, and way too much time spent trying to solve the math problems compared to giving feedback'. Giving feedback was a lot easier, at first much of the time was spent on navigating the iPad rather than providing feedback, but this trend decreased as students got used to the interface.
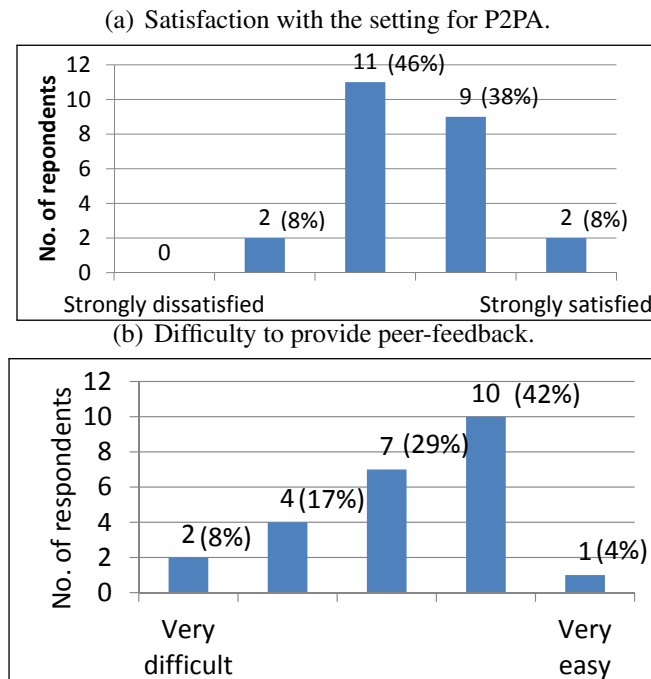


Figure D.6: Opinions on P2PA model.

The students expressed mixed opinions on the mathematic assessment rubric that was given to them. Some thought it was good and well defined, but others could not well understand the criteria. It was suggested that 'the main focus should be on giving a written comment instead of giving a mark for each separate criteria'. There is a clear indication that students need more skills to act as assessors.

The peer-feedback was found helpful by 66.6% (16) of the participants, the reasons being the opportunity to understand and correct their own mistakes, in addition to increasing their confidence to perform the given tasks. Some of the students (high-performer) noted that they could recognise their mistakes themselves by seeing the correct answersheet, but others didn't read the feedback because they were exhausted by the end of the experiment.

P2PASS has also a motivational factor among other things. The students mentioned that the idea of peer-feedback made them spend more time on their studies and work harder. There is also a "feel good and positive competition" element

because students can help others and see "how well others have done and then compare them to oneself".

Student collaboration was another aspect of study in this paper. Students worked in groups of 3 students, and at the end of the experiment, it became clear that it was important for them to work together. A student stated that "Collaboration makes participants work as a team and discuss ideas. This in turn increases the knowledge of participants". The results here obtained, emphasise the need to foster collaboration among students since it helps them not only for knowledge acquisition but also for developing their social skills.

### 4.2.2 Students' opinions on the usability of technology-supported P2PASS

Generally, the system suitability for learning scored low. Users found difficult to learn the system functionalities, hence conformity with user expectation was also low. Since the learnability was low for the majority of users, the effectiveness was greatly affected as the experiments took longer than expected (average duration was 3 hours).

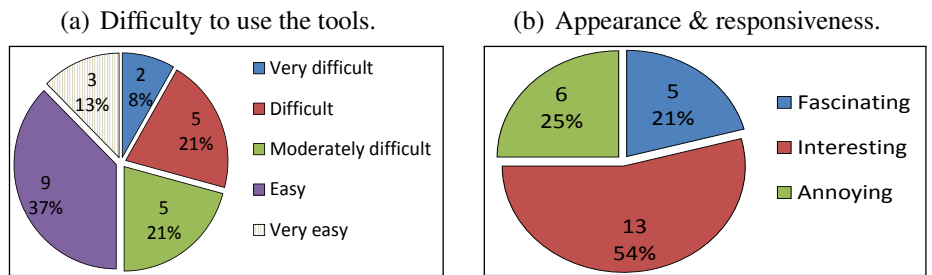Participants expressed usability problems related to the system responsiveness



(a) Difficulty to use the tools.    (b) Appearance & responsiveness.

Figure D.7: Opinion on P2PA tools.

and interaction, the user interface was not very intuitive and iOS "apps dependent" file management system is not user friendly. The user guidance of the mobile applications that were used was also poor : there were no detailed error messages and some of the actions were not confirmed upon execution; hence prompting the users to repeat the same action several times. On the other hand, however, there are also indications of improvements in suitability for the task as users get used to the system.

Despite some difficulties to use iPad, the concept was much appreciated; with statements such as "Portability is important. The touch feature of the iPad is also better than a mouse, since you can draw and write uncommon sign without a lot of hassle. The size, weight and battery power is also important" and "It might help in the sense that you'd be able to check out feedback and such at any time, any place".

### *4.3 Challenges and potential improvements*

This study encountered the challenges concerning the students' involvement, conceptual understanding of peer-assessment as well as technology adoption. Students did not respond well to the invitations to participate in this study. As a recruitment strategy, participants were rewarded with the university bookstore gift cards, and in some cases their participation was considered instead of a compulsory coursework. Further on, peer-assessment concept was new to the students and there were concerns regarding the quality of feedback they might receive from their peers, the additional workload involved and the potential impact on their final grades. As it was mentioned earlier, participants were concerned about their lack of necessary skills in mathematics assessment; hence we suggest that a system should be put in place to enhance the students' judgment capacity and foster the active role of students as assessors.

Peer-feedback is one of the good approaches to formative assessment, especially in large classes because it would be very difficult for a teacher and very costly to provide regular individual feedback. It is also suggested that students work in groups in order to foster collaborative learning since it proved beneficial in this study.

The participants also expressed issues related to the technology tools used in this study, not only because they were not familiar with the tools, but also because the tools were not necessarily designed for mathematics peer-assessment purposes. The problems range from file management to finding the right tools such as the pen colors and sizes. The user control was limited as well, and in some cases participants could not easily find their way to perform a desired task or go back from an unwanted function. It was challenging for participants to recognise and recover from errors, since the users were not timely informed on the system status (success or failure). Improvements can focus on training the students on the available tools while working towards a development of an integrated tool.

## 5. Conclusions

This paper presented results of iPad mobile tablet technology-supported P2PASS experiments for two mathematics courses. The study confirmed that peer-assessment can foster student engagement and responsibility in their learning. In addition to portability, connectivity and mobility features of the iPad, this study has proved the advantages of tablet technology in writing mathematics expressions, and this can

be time saving especially in providing an elaborate (step by step) feedback. However, this study found no clear evidence of the benefits to use iPad in solving math problems. The technology acceptance was found greatly dependent on how well the peer-assessment could be planned especially in regards to students' training on how to use the tools.

Future research is required to find the effectiveness of the P2PASS carried out over a period of time. This would be necessary to exclude the effects of learnability issues and to enable the measurement of the potential impact on students' performance. It is also desirable to carry out the same experiments with students of a different social and ethnographic background since collaborative learning could be affected by such parameters. The iPad is easy to use in general but the current set of available applications and LMS solutions are not well integrated and prevent an efficient use for P2PASS. This may change once iPad-like devices are cheaper, more widely spread, and when more integrated solutions have evolved.

## REFERENCES

[1] M. AL-Smadi, C. Guetl and F. Kappe, "Peer assessment system for modern learning settings: Towards a flexible e-assessment system", *International Journal of Emerging Technologies in Learning (iJET)*, vol. 5, 2010.

[2] L. Brodie, B. Loch, "Annotations with a Tablet PC or typed feedback: does it make a difference?", *Proceedings of the 20$^{th}$ Australasian Association for Engineering Education Conference, (AAEE 2009)*, Adelaide, Australia, 2009, pp.765-770.

[3] C. Chen,"The implementation and evaluation of a mobile self- and peer-assessment system", *Computers and Education*, vol. 55, pp.229-236, 2010.

[4] A. Clauss. 2011. *iCab Mobile - Web Browser*.[Online]. Available: http://www.icab-mobile.de/

[5] L. de-Marcos, J. R. Hilera, R. Barchino, L. Jimenez, J. J. Martines, J. A. Gutierrez, J.M. Gutierrez, S. Oton, "An experiment for improving students performance in secondary and tertiary education by means of m-learning auto-assessment", *Computers and Education*, vol. 55, pp.1069-1079, 2010.

[6] G. Egodawatte, "A rubric to self-assess and peer-assess mathematical problem solving tasks of college students", *Acta Didactica Napocensia*, vol.3, no.1, pp. 75-88, 2010.

D

[7] N. Falchikov, "Involving students in assessment", *Psychology Learning and Teaching*, vol. 3, no.32, pp. 102-108, 2003.

[8] G. M. N. Isabwe, H. Øysæd and F. Reichert, "On the Mobile Technology Enabled Peer-Evaluation: A User Centric Approach", in *Proceedings $7^{th}$ Annual International Conference on Computing and ICT Research (ICCIR11)*, Makerere, Uganda, 2011, pp. 272-285.

[9] J. Nielsen and T. K. Landauer, "A mathematical model of the finding of usability problems", in *Proceedings of ACM INTERCHI'93 Conference*, pp. 206-213, 1993.

[10] J. Nielsen, "Estimating the number of subjects needed for a thinking aloud test", *Int. J. Hum.-Comput. Stud.*, vol.41, pp. 385-397, 1994.

[11] Pearson Plc.2011.*Fronter Learning Management System*.[Online]. Available: http://com.fronter.info/.

[12] M. L. Wen, and C. Tsai, "Online peer assessment in an inservice science and mathematics teacher education course", *Teaching in Higher Education*, vol.13, no.1, pp. 55-67, 2008.

# Appendix E

# Paper IV

| | |
|---|---|
| **Title:** | A Novel Approach to the Application of Semantic Web Technologies To Student Centred Learning |
| **Authors:** | **Ghislain Maurice Norbert Isabwe**, Frank Reichert and Morgan Konnestad |
| **Affiliation:** | University of Agder, Faculty of Engineering and Science, Jon Lilletuns vei 9, 4879 Grimstad, Norway |
| **Published in:** | *Proceedings of IADIS International Conference Mobile Learning 2012. Berlin, Germany*, March 2012. |

E

# A Novel Approach to the Application of Semantic Web Technologies To Student Centred Learning

Ghislain Maurice Norbert Isabwe; Frank Reichert and Morgan Konnestad

University of Agder

E-mails: {maurice.isabwe, frank.reichert, morgan.konnestad}@uia.no

*Abstract* —**This paper addresses student centred learning in mobile environments. The challenges of student centred learning implementation are the requirements to provide learning resources/services according to the needs of individual students and adaptability to dynamically changing student contexts. The concept of student centred learning places the student at the centre of teaching and learning, and the student has more responsibility and ownership of his/her learning. This paper proposes the application of semantic technologies to create a mobile learning context model in order to support the student centred learning environments. A context-aware mobile learning ontology is presented, together with rules that are applied for reasoning on learning resources/services which would be considered by the student. The paper provides learning scenarios with rule based reasoning, and suggests a student centred learning service architecture.**

*Keywords*—Context-awareness, mobile learning, semantics, ontology.

E

## I. INTRODUCTION

The quest for excellence in education has driven research efforts both in pedagogical models and educational technology over many years. Recently, it was argued that future teaching and learning will embrace new technology enabled constructivist learning concepts, including the use of mobile technology to improve the students' engagement in the learning process [3]. In this context, the student is active and the emphasis is put on what the student does in order to acquire knowledge or skills. This will involve a high level of student's choice in education and customization of learning to suit different individuals.

In the late 90's, Hannafin et al. [2] discussed technology-enhanced student centred learning environments, with the identification of their foundations and assumptions. Through a review and a critical analysis of such environments, the authors noted the potential to address individuals' learning interests, and enhance the learners' thinking ability as well as their understanding. On the other hand however, the implementation of technology supported student centred learning environments, involves complex processes in terms of pedagogic conceptual adaptation and optimization of adopted technology tools.

Our approach capitalizes on students' ability to make choices on what they want to learn, how they prefer to learn it and their context information such as the location, time and the activity among others. The aim is to assist the students in making their choices while being encouraged to identify their needs, to explore the available learning opportunities, to reason and to learn what they believe is necessary and meaningful.

This paper presents in section 2 an overview of related work, comprising of a literature review of context-aware mobile learning. In section 3, a context-aware mobile learning ontology is discussed and, in section 4, a semantic web rules language is used for rule based reasoning on scenarios of student centred learning. The last section is a conclusion with future directions.

## II. CONTEXT-AWARE MOBILE LEARNING

Mobile learning, a modern concept of using mobile technology in teaching and learning, has seen an increasing interest among educators and researchers. Context-aware mobile learning is of special interest because of the context dimension which is defined as "any information that can be used to characterize the situation of an entity [1]"; and the awareness as used in context-aware systems, whereby the awareness stands for the use of "context to provide relevant information and/or services

to the user, where relevancy depends on the user's task" [1].

Lehsten et al. [5] proposed an extension of Learning Management Systems to provide personalized mobile learning services. It is suggested that using mobile device features like positioning, acceleration sensors, or the camera, the user's intentions are detected. Then, based on the knowledge of user's location and timetable, helpful and interesting university services are offered, such as the location-sensitive lecture streaming, guiding the way to books recommended by the lecturer in the library, campus navigation, accessing optimized lecture notes for mobile devices and using ubiquitous features of the whole university computing infrastructure. It is noted that, in this work, context information was only limited to time and location.

Furthermore, another study considered user perceptions and preferences for a context-aware personalized mobile learning application [9]. The authors carried out an interview study of individual mobile learning preferences comprising of the location of study, noise or distraction levels in a location and the time of the day. The typical locations of study were sorted into study-dedicated areas, home areas, cafes and transport facilities. It was mentioned that preferred locations are related to factors affecting student concentration levels such as noise, busyness of the environment, temperature, light and layout of the room, motivation, time of the day and urgency of the task. The authors argue that current location, noise level, and time of day can be detected to determine appropriate learning materials for a student profile (preferred location of study, preferred noise level and preferred time of day). That study does not provide details of how appropriate learning materials are defined.

In a separate study, Moore et al. [6] discussed the effective creation and implementation of an individual profile, termed as context. They defined two general types of context: a static context (customisation) in which the user is actively involved in making the profile and, a dynamic context (personalisation) whereby the system detects, analyses and reacts dynamically to the user's behavior. Subsequent to user profile creation, context matching and processing was carried out in order to enable an effective use of contextual information. Through a scenario based evaluation and simulation, context matching and context processing rules were tested out using semantic web technologies. Context matching may prove difficult if there are highly dynamic context factors as well as possibilities to encounter anomalous or ambiguous contexts.

Context in mobile learning can be modeled using the ontology, which is a specification of a concept. The ontology is used to present and organize a learner's context and, a context-aware mobile learning model can be constructed based on ontology and case-based reasoning approach.

In the next sections, we present our approach to context-aware mobile learning. The novelty of our approach resides in the combination of mobile technology aspects for user profile building and the user's ability to supply context information as well as the selection of learning resources. Here the focus is put on reasoning on the student's context and learning style in order to suggest to him/her the learning resources/services.

E

### III. CONTEXT-AWARE MOBILE LEARNING ONTOLOGY

Mobile learning can play an important role in enabling student centred learning. A student can choose his/her preferred learning style and, given today's mobile devices capabilities, some of the student's context information such as time, location and activity can be detected and used for learning purposes. Furthermore, the student can be involved in manual creation of his/her profile using a mobile device.
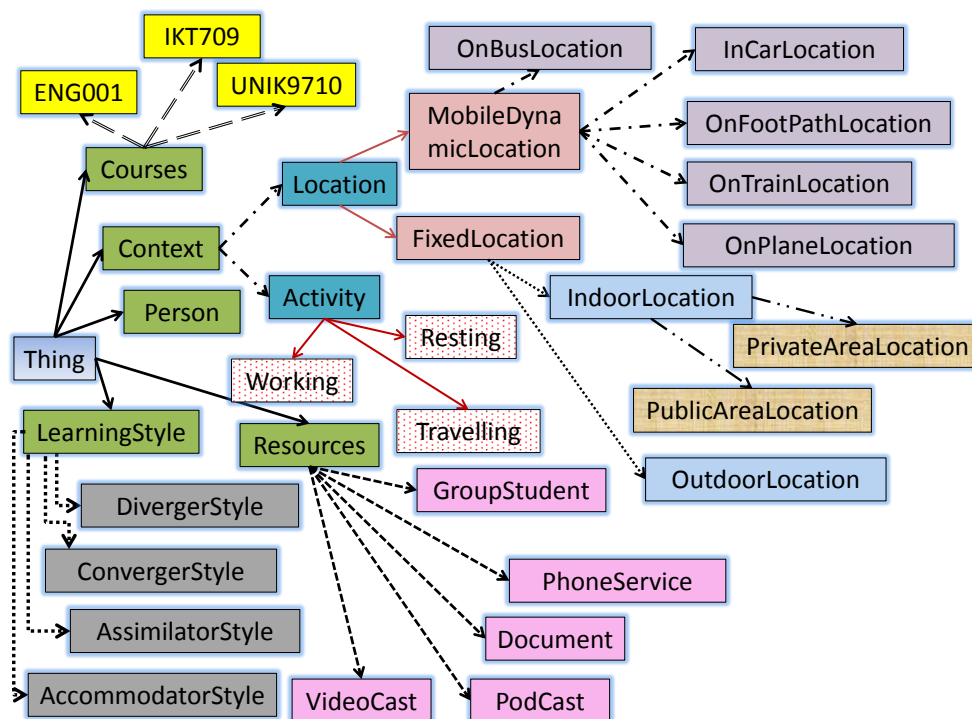


Figure E.1: Context-aware mobile learning ontology

Figure E.1 illustrates a context-aware mobile learning ontology that was developed with Protégé [8] Web Ontology Language (OWL) editor. Generally, the ontology, as a specification of a domain concept, explicitly describes the context elements

and defines the relationships between the entities in terms of object properties and data properties. OWL offers the capability to create four ontology components: (i) concepts, (ii) instances, (iii) relations and (iv) axioms. In this work, we suggest 5 main concepts to describe a context-aware mobile learning domain.

1. Courses: This is a class with subclasses representing the specific courses that are offered. Course classes such as "IKT709" will also have "instances" to represent courses that are offered during a particular academic year or semester.

2. Person: This is a class whose individual entities represent the students. It helps to collect individual students' data such as names and contact addresses.

3. Context: a student context is comprised of his/her current activity and location.

   (a) Activity : Three main sets of activities are defined as follows:

      i. Working: All activities directly related to the studies. These can include tasks such as working on an assignment, laboratory work or group study. Such activities can take place both during the official study time or any other time when the student works on his/her own initiative. This kind of context information can be collected onto the ontology through customisation.

      ii. Travelling: Any activities that involve moving from a point in space to another. This context information helps to determine appropriate formats of learning materials; for example, due to safety reasons, we would not expect a student to be able to read course notes while riding a bike.

      iii. Resting: All activities during which the student is not supposed to be studying. These include activities such as sleeping, socializing with friends and sporting just to name a few. We assume that these activities take place during the student's free time, which is out of official studying hours. Therefore, the context aware mobile learning system should only suggest such learning activities that are not compulsory and might not disrupt the student's right to rest. For instance, it would not be necessarily appreciated if a student was to receive an alarm message while he/she is sleeping.

   (b) Location: We have defined two main sets of locations:

      i. MobileDynamicLocation: This is defined as a set of locations where a student can be while travelling. We consider that a student can be on a bus, in a car, on a foot path, on a train or a plane. It is noted that

> although the list may not be exhaustive, it gives a good indication of possible mobile locations.

> ii. FixedLocation: This is a complement set to the previous one (Mobile-DynamicLocation). It comprises of locations in which the student is not moving in space, with consideration to both indoor and outdoor environments. For instance, the indoor locations can be subclassified into public and private areas.

In addition to the activity and location, we have considered four learning styles with reference to Kolb's learning styles [4]. Using a self-descriptive inventory, Kolb measured differences in learning styles and he identified four most significant learning styles. It is noted that, in this paper, we have appended each learning style with the word "Style" for the sake of consistency in the naming of "learning concept":

4. LearningStyle:

   (a) DivergerStyle: This style refers to a way of knowledge development through a combination of Concrete Experience (feeling) and Reflective Observation (watching) of the environment around the student. Students in this category dispose of strong imaginative abilities, and they are capable of discerning concrete situations from a multitude of viewpoints and ideas.

   (b) ConvergerStyle: Students with this learning style prove to have dominant Abstract Conceptualisation (thinking) and Active Experimentation (doing) learning abilities.

   (c) AssimilatorStyle: The learning is achieved through thinking (Abstract Conceptualisation) and watching (Reflective Observation). Students with this learning style are said to be capable of inductive reasoning as well as model and theory creation.

   (d) AccommodatorStyle: This learning style is marked by the strengths in Concrete Experience and Active Experimentation. Students who fall in this category are those who are more involved in doing things, making new plans and experiments as well as taking part in new experiences.

5. Resources: The resources describe services and learning materials that can be offered to the student. For instance, the system can deliver messaging services such as alerts and announcements in addition to providing podcasts and lecture videos. Reading materials are also another form of resources that can be offered in this context.

## IV. Rule based reasoning for a student centred learning environment

In order to implement a student-centered learning environment, each student's profile is collected into the ontology. Profile elements consist of a student bio-data, course of study, context, and learning style.
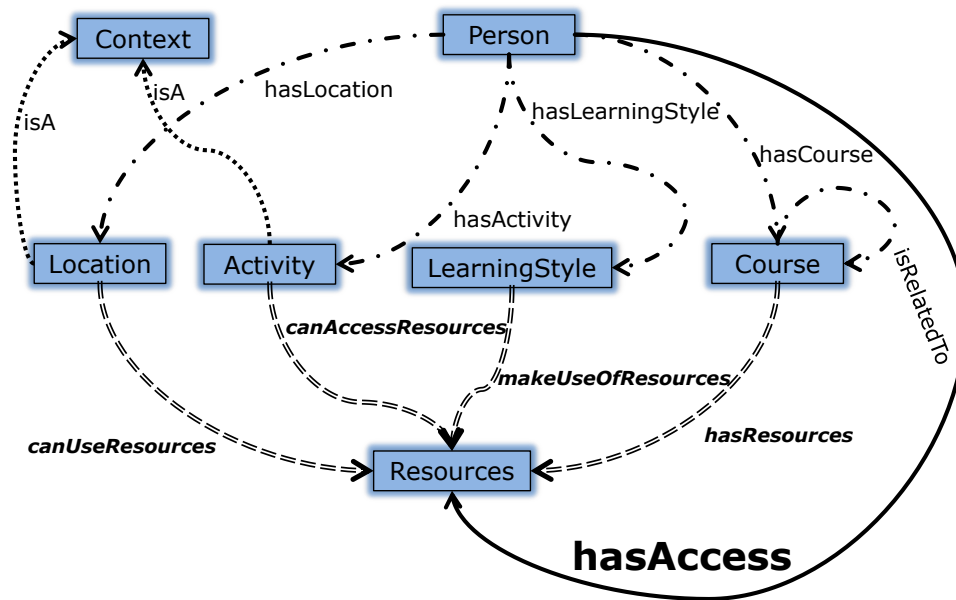
Figure E.2: Rule-based reasoning for a student centred learning

Figure E.2 shows the ontology's entities and relationships that are used for reasoning on the learning resources/ services offered to different students. Given the student's activity at a given time, location, learning style, and the course of study; the student can be offered learning resources (services) accordingly. These services include the provision of course materials in the form of documents (reading materials) and podcasts (here called VideoCast/ AudioCast), as well as a messaging service (PhoneService) for alerts and announcements. Using the Semantic Web Rules Language (SWRL), rules are written so that a reasoner can infer the learning resources that will be offered to a given student. The logic behind the reasoning is that the student should be allowed to choose whether he/she would like to have access only to those resources according to the context and learning style or to have access to an extended list with priorities of resources following predefined rules.

In order to illustrate the rule based reasoning, in the next subsection, we present 4 scenarios showing how the student can be offered learning resources. The scenarios are built on the context information presented in the ontology given above, the learning styles as well as the courses of study. As a proof of concept, the scenarios were implemented using OWL DL and SWRL in Protégé.

### 4.1 Student centred learning scenarios

Annie is a student who has enrolled on an English course. Her learning style was predefined as a "Diverger", and she is at the moment working (individual study) at home. Annie's learning style was set manually(customisation) and her activity and location information are being dynamically collected by a mobile device (personalisation) onto the ontology. Annie should be given access to learning resources that are appropriate to her current profile and, she should be able to make choices as to have access to a wider range of materials (less profile related restrictions). Therefore, four rules are added on the ontology to make that possible. Rule number one is first applied in response to Annie's profile (context and learning style), and then Annie is given an option to choose her preferences on additional learning materials. The implementation of the rule based reasoning is achieved with JESS rule engine (Sandia, 2008).

- Rule 1. Access to resources restricted to the student's context and learning style:
  *Person(?P)ˆ Course(?C) ˆ hasCourse(?P;?C) ˆ hasResources(?C;?R) ˆ hasActivity(?P;?A) ˆ hasLocation(?P;?L) ˆ canAccessResources(?A;?R)*
  *ˆ hasLearningStyle(?P;?l) ˆ makeUseOfResources(?l;?R) ˆ canUseResources(?L;?R)*
  $\rightarrow hasAccess(?P;?R)$

  Subsequent to the reasoning on this rule, the rule engine has inferred that Annie can have access to an English course Videocast (lecture video). This is based on her learning style, which suggests that she can learn by watching a video, her activity which is studying and the home as a 'private area location'. The 'studying' activity can access 'VideoCast' resources and the 'private area location' can use the 'VideoCast' resources as well. The same rule also had first to check on Annie's course of study in order to return English learning resources.

  In addition to the inferences from rule number 1, using the available OWL APIs; there is a possibility to generate a request for Annie to trigger the reasoning on the rules number 2 to 4 so that she can have access to an extended range of learning resource as presented in the next rule scenarios.

- Rule 2. Access to resources relevant to the student's course of study and learning style:
  *Person(?P) ˆCourse(?C) ˆhasCourse(?P;?C) ˆhasResources(?C;?R) ˆhasLearn-ingStyle(?P;?l) ˆmakeUseOfResources(?l;?R) → hasAccess(?P;?R)*

- Rule 3. Access to all resources relevant to the student's course of study:
  *Person(?P) ˆCourse(?C) ˆhasCourse(?P;?C) ˆhasResources(?C;?R) → hasAccess(?P;?R)*

- Rule 4. Access to resources from all courses related to the student's course of study:
  *Person(?P) ˆ Course(?C) ˆ hasCourse(?P;?C) ˆ hasResources(?C;?R) ˆ isRelat-edTo(?C;?T) ˆ hasResources(?T;?Z)→ hasAccess(?P;?R)ˆhasAccess(?P;?Z)*

### *4.2 Student centred learning environment*
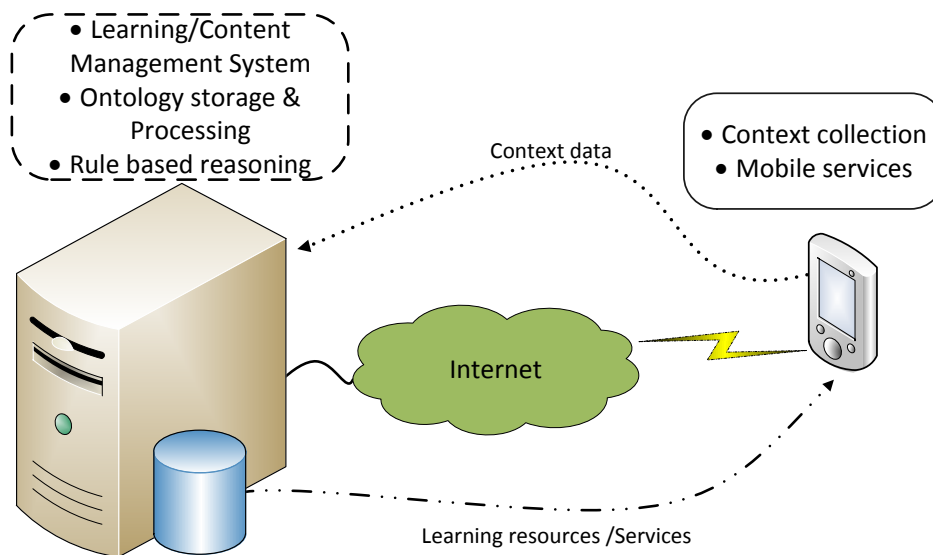


Figure E.3: Student centred learning service architecture.

A student centred learning environment can be enabled through the integration of ontology based mobile learning context model and a learning management system (LMS).

Figure E.3 presents a student centred learning service architecture, consisting of an enhanced LMS which handles the ontology storage, processing and reasoning

together with a mobile device which handles the context data collection as well as learning resources delivery. Our approach proposes to make use of Protégé OWL API (Application programming interface) in order to define the interactions between the ontology and the existing LMS which can host the learning resources on one hand. On the other hand, using the mobile operating system API, a mobile application can be defined to push context data into the ontology. Subsequently, a rule engine will reason on the context data so that new (updated) instances of learning resources can be generated and exported into the ontology. Once the ontology is updated, the mobile application should retrieve appropriate learning resources from the LMS.

### V. CONCLUSION

Student centred learning as opposed to teacher centred learning not only places the student at the centre of the learning process but also seeks to improve the learning efficiency through active learning. This requires the consideration of the student's profile and the student's ability to control their learning. The student profile can be established and regularly updated both manually and automatically using the sensors embedded in mobile devices.

With the knowledge of students' context information, personalized services can be offered to the students. Students are involved in this mobile learning model both in building their profile on which the reasoning on learning resources is done, and choosing the resources that they want to use for learning. This paper discussed the development of a mobile learning ontology, and a rule based reasoning for efficient implementation of student centred learning environments.

Our implementation has considered OWL DL together with SWRL, and it has enabled access to learning resources according to both the student's profile (context and learning style) as well as the student's choice of learning resources. Since this work has proved the viability of semantic web technologies for student centred learning, future work will consider additional aspects of learning such as students' understanding levels and learning performance for advanced reasoning on learning resources and services.

### REFERENCES

[1] A. K. Dey, "Understanding and using context", *Personal and Ubiquitous Computing*, vol. 5, no.1, pp.4-7, 2001.

[2] M. J. Hannafin and S. M. Land,"The foundations and assumptions of technology-enhanced student-centered learning environments", *Instructional Science*, vol. 25, no.3, pp.167-202, 1997.

[3] G. M. N. Isabwe, H. Øysæd and F. Reichert, "Future concepts for university teaching and learning", in *Proceedings of IADIS International conference Mobile Learning*. Avila, Spain, pp. 307 - 309,2011.

[4] D. A. Kolb, "Experiential learning: experience as the source of learning and development, *Prentice Hall*, Englewood Cliffs, NJ, USA, 1984.

[5] P. Lehsten, R. Zender, U. Lucke, and D. Tavangarian, "A service-oriented approach towards context-aware mobile learning management systems", in *Proceedings of the 8$^{th}$ IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops)*. Mannheim, Germany, pp. 268-273, 2010.

[6] P. Moore, B. Hu, M. Jackson, and J. Wan, "Intelligent context for personalized mobile learning", in *Proceedings of International Conference on Complex, Intelligent and Software Intensive Systems*. Fukuoka, Japan, pp. 247-254,2009.

[7] Sandia National Laboratories, "Jess rule engine", 2008. Available on http://www.jessrules.com., Accessed on 16/01/2012.

[8] Stanford Center for Biomedical Informatics Research - SCFBIR, "Protégé-OWL editor", 2011. Available on http://protege.stanford.edu/overview/protege-owl.html. Accessed on 16/01/2012.

[9] J. Y. K. Yau and M. Joy, "A context-aware personalized m-learning application based on mlearning preferences", in *Proceedings of the 6$^{th}$ IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education*, Kaohsiung, Taiwan, pp. 11-18, 2010.

E

# Appendix F

# Paper V

| | |
|---|---|
| **Title:** | Investigating the Usability of iPad Mobile Tablet in Formative Assessment of a Mathematics Course |
| **Author:** | **Ghislain Maurice Norbert Isabwe** |
| **Affiliation:** | University of Agder, Faculty of Engineering and Science, Jon Lilletuns vei 9, 4879 Grimstad, Norway |
| **Published in:** | *Proceedings of 2012 International Conference on Information Society, (i-Society)*, London, United Kingdom, June 2012. |

F

# Investigating the Usability of iPad Mobile Tablet in Formative Assessment of a Mathematics Course

Ghislain Maurice Norbert Isabwe

Faculty of Engineering and Science, University of Agder

Jon Lilletuns vei 9, 4879 Grimstad, Norway

E-mail: maurice.isabwe@uia.no

*Abstract* —**Formative assessment allows students to judge their learning progress against a given standard or assessment criteria during the course of study. There are challenges related to the generation and delivery of feedback for formative purposes, for instance the students' engagement in their learning, the pedagogy adopted and the usability of the technology tools used in this regard. This paper presents a study of iPad mobile tablet technology-supported peer-to-peer assessment (P2PASS), which is a modern form of formative assessment. The experimental work was undertaken at Kigali Institute of Science and Technology (KIST) in Rwanda. The implementation of P2PASS in this study shows the students' engagement in learning mathematics, and allowed the investigation on the possibilities of improving their mastery of the subject. This paper further discusses the students' attitudes towards the P2PASS process as well as the technological tools used. The usability problems of the iPad applications are discussed, together with the implications of using mobile tablet technology in providing the feedback on the mathematical work.**

*Keywords*—Mobile technology, usability, peer-assessment.

F

## I. INTRODUCTION

Every engineering student must take mathematics course(s) at some point of his/her education. Hence, there is a constant need to improve the ways of teaching and learning mathematics. The student centred learning concept emphasises the importance of student engagement and responsibility in learning; in addition to that, the advancements in information and communication technology have increased the opportunities of technology-supported teaching and learning. The future learning processes are likely to continue evolving from the behaviourist and cognitivist learning theories towards constructivist learning and social learning.

Constructivist learning is founded on the abilities of students to be actively involved in the construction of knowledge based on personal experiences. That theory of learning is well suited in the media-rich environments, which can facilitate the exploration of the new approaches to learning such as the active learning. Active learning requires ownership of the learning and progressive judgement of the mastery of subject, which should take place regularly during the course of study. This judgment, known as "formative assessment", can help the learner (student) to measure progress against a certain standard or reference in order to timely bridge the gap that may exist between the level of knowledge of the student and the learning goal.

Formative assessment of the mathematics is of special interest since it requires judgment on every step of the answer. Hence, the assessor should be able to provide feedback on different elements of the answer: (1) the correctness of calculations, (2) the understanding of methods and procedures and (3) the easiness of reading and understanding the mathematical expressions. Additionally, it is important to mention and correct the mistakes/errors at the point where they appear on the student's answer-sheet rather than at the end of all answers. This work proposes a new approach to formative assessment in mathematics courses, supported by mobile tablet technology. The strengths of mobile computing are combined with the features of a Learning Management System (LMS) to facilitate the provisioning of students-generated feedback. The experimental investigations were carried out to assess the pedagogical aspects and technical usability of the model.

The next section presents the research goals of this work, followed by a literature review of related work presented in section 3. In section 4, the paper presents the methods used for the investigations and section 5 discusses the findings and limitations encountered. The final section draws conclusions and gives the future directions.

## II. Research goals

The goal of this work is to study the formative assessment; in order to devise the processes of technology-supported P2PASS. Then, to carry out a field study to investigate the usability of our proposed approach, as applied to a mathematics course. Finally, the researcher observes the participants' behaviours while completing the given task, and he administers a survey at the end in order to collect data on the following points:

- Pedagogical aspects: What are the students' attitudes towards the peer-to-peer-assessment? Does the P2PASS motivate and engage students? How do the students, in collaboration with others, solve mathematics problems? What do students think about peer-feedback in general?

- Usability: What are the technical usability problems that students may find while using the iPad mobile tablet for peer-feedback provision?

## III. Related work

As the interest in mobile learning increases in different educational settings, studies are being undertaken towards the use of mobile devices for assessment purposes [1][2][3]. Consideration is given to the potential of mobile learning, in terms of the mobility, the availability and flexibility of learning. The challenge is to know how the educational strategies such as the peer-assessment can be practically supported. The literature suggests that the students could benefit from mobile peer-assessment, given that there would be multiple assessments, hence allowing the students to improve their work after each assessment.

In his work on formative assessment, Sadler [4] discussed how the appraisal of the student's work can help to improve his/her competence; stressing the importance of multiple criteria in assessing the student's work where the answer may not simply be right or wrong. This kind of assessment requires the assessor (student) to have the necessary skills to judge the quality of work, in order to provide a valid, meaningful and fair feedback. The assessor should have an idea of the goal or the reference level in order to compare that with the work to be appraised, and then advise on the necessary action towards meeting the reference level (specifically by providing a constructive feedback to suggest how the gap between the current performance and the reference level can be bridged).

Although several studies [5][6][7] have acclaimed the positive impact of formative assessment, there are also concerns about the efficiency of methodologies

F

and designs that are used in this regard. Therefore, there is a need to establish a framework for the best practices to maximize the benefits of formative assessment [8]. Aoun [9] revisited the effectiveness of peer-assessment, and he argued that the problems with the peer-assessment are results of the process, meaning the implementation, rather than the product which means the concept. An effective implementation of the peer-assessment process should be emphasised in order to realise the educational benefits of peer-assessment as a concept.

For a successful implementation of the technology-supported peer-assessment, attention should be paid to the pedagogical aspects and the technological aspects as well. Technology-supported peer-assessment carries a learning component which can be appreciated to a certain extent with reference to the pedagogical usability criteria introduced by Nokelainen [10]. The author defines the pedagogical usability as a "sub-concept of utility" (derived from a classification by Nielsen [11] where the utility "refers to the ability of the system to generally provide functions that corresponds with the needs of the users"). Out of the ten pedagogical usability criteria that were identified in [10], we can mention four which are closely related to peer-assessment: (1) the learner's activity, (2) goal orientation, (3) motivation, and (4) feedback.

The concept of technical usability is of a great importance for the success of any product that is intended for human interaction. Studies into technical usability spanning more than two decades, have mainly addressed how the people who use a product might be able to easily and quickly accomplish their task(s)[12][13]. Usability studies are concerned with the system characteristics such as the ease of use, efficiency (time spent on the task), effectiveness (task completion by the users), learnability or easiness to learn, aesthetics (appearance) and the user satisfaction which relates to how the user feels towards using the system. Measuring the usability of technology-supported learning systems is needed in order to know what the intended users (students) think about the system; and it is arguably believed that this can play a key role in the technology adoption of the system. In his work on perceived usefulness, perceived ease of use and acceptance of information technology, Davis [14] found a significant correlation between the usage and perceived usefulness as well as the perceived ease of use. It was suggested that users are likely to adopt an application primarily because of the functionalities it has, and then consider how easy or hard it is to use, even though they would be often willing to adjust to the difficulties of use. The author stressed the importance of usefulness because a non-performing system cannot be adopted even if it is very easy to use.

## IV. METHODS

This work reports on findings of a field study consisting of experiments carried out in a controlled environment. The study was conducted during the month of December of 2011 at Kigali Institute of Science and Technology (KIST), a public institution of higher learning in RWANDA (Africa). This institution was chosen mainly because it offers a wide range of engineering courses, for which students have to learn mathematics in classes of more than 150 students. Usually, mathematics at this institution is thought without any technology support, i.e. in a traditional lecture mode. Hence there is a risk of the teacher not being able to follow the progress of all students on a regular basis. Furthermore, KIST aspires to implement technology-supported teaching and learning across all subjects in the near future, thus it would be necessary to understand the students' opinions on this issue. It is in this regard that students were given iPad mobile tablet computers and the instructions on how to use the devices for solving mathematics problems as well as providing feedback on the work of their peers. Figure 1 shows the students' sitting arrangement during an experiment.
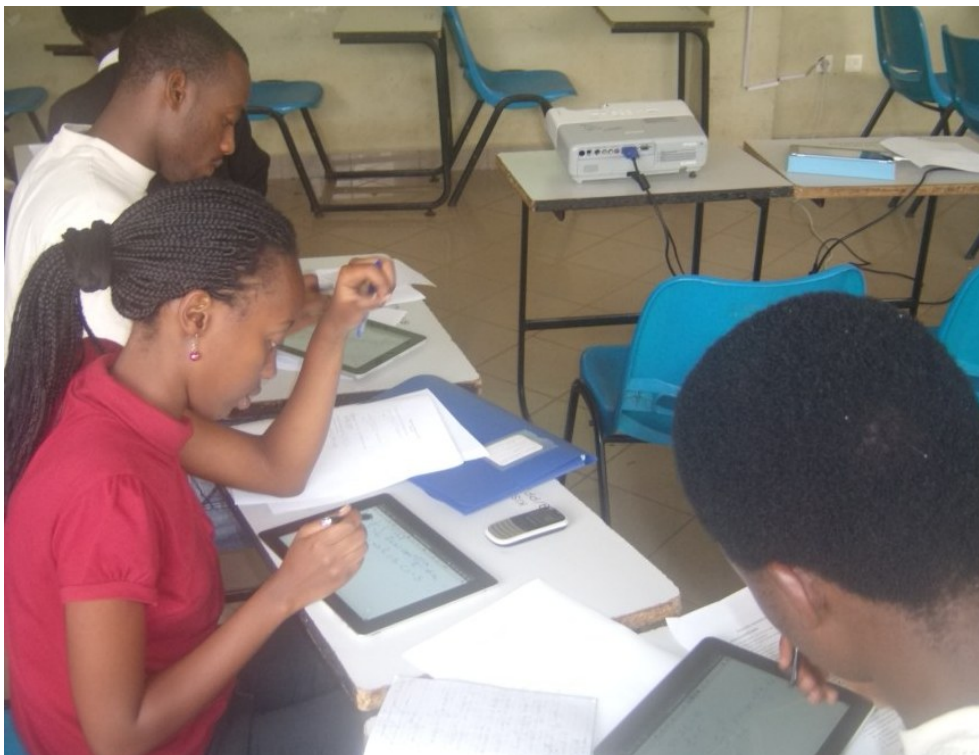


Figure F.1: P2PASS experiment session

The participants to this study were second year students in Civil Engineering, Water and Environmental Engineering and Civil Engineering and Environmental Technology as well. In a total of 27 participants, 22 (6 females and 16 males) responded to the survey questionnaire. The participants' ages vary from 18 to 25 years old; and all of them had neither a previous experience with the peer-assessment process nor with the iPad mobile tablet computers.
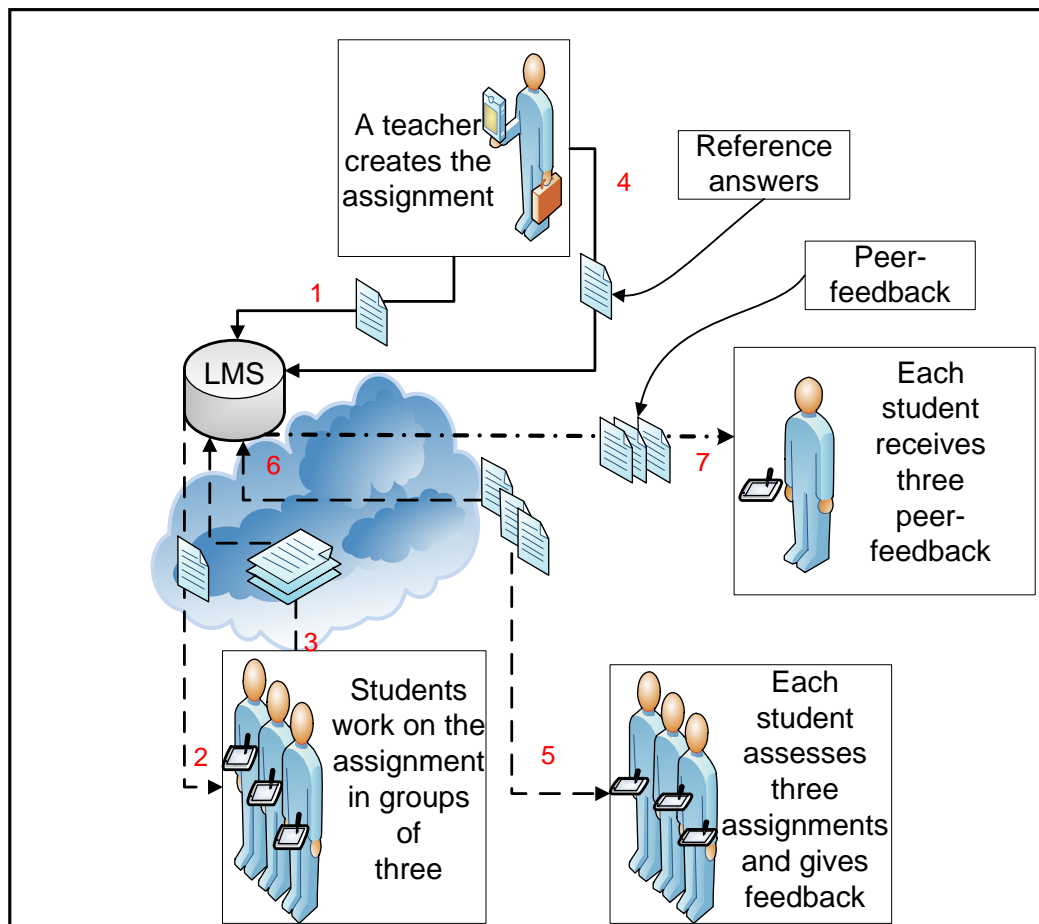


Figure F.2: P2PASS functional model

Before the experiments started, a mathematics lecturer provided the assignments on the module that he was teaching at the time (Fourier series). The assignments consisted of a set of questions to be uploaded onto an LMS at the beginning of the experiment and the reference answers to be shown to students after they have solved the questions themselves. Figure 2 illustrates the P2PASS functional model. Subsequent to a 15 minutes briefing session about the peer-assessment process and the technological tools, students were requested to work in groups of three so that they

could collaborate in problem solving. Each student was given an iPad mobile tablet computer and the individual students' accounts on the LMS were provided for the students to access the assignment, as well as to submit their answers for assessment. Once a student completed an assignment, it was uploaded on the LMS, in order to allow other students to assess the work and provide feedback (peer-feedback). Each student was given access rights to the individual folders of three other students in order to assess them, so that everyone will have up to three peer-feedbacks at the end. Every iPad was running iOS v.5 operating system, and peer-feedback was supported by the PDF Expert v.3, an iPad application for editing and annotating documents of portable document format (PDF).

The mathematics assessment rubric shown in Figure F.3 was explained to students for them to understand the assessment criteria to follow in assessing their peers' work. Then the correct answers were made available to the students as a reference, in order to allow them to judge their performance level.

Marking was done primarily by writing on the touch screen either using a stylus pen or a finger on the answer-sheet as a PDF document, but it was also possible to type the review comments using the integrated keyboard. All documents (the questions, students' answers, reference answers and marked answer-sheets) were handled through "Fronter" LMS.

Data collection methods consisted of direct observations by the researcher, semi-structured interviews with participants and a survey questionnaire. The questionnaire, which was delivered online at the end of the P2PASS sessions, comprised of closed-ended questions and open-ended questions focusing on the pedagogical aspects and the technical usability of the mobile technology-supported peer-assessment. Then quantitative methods were used to evaluate the students' opinions measured on a 5-point Likert scale, and the qualitative methods were used to evaluate the answers to the open ended questions and the interviews' responses.

## V. Results and Discussions

### A. *Survey results and observations*

The P2PASS study was conducted in a series of experimental sessions with five to seven participants each time. The same researcher was there to administer the experiments and observe the participants' behaviours as they undertake the tasks of answering the given mathematics exercises, peer-assessing the answers and answering the survey questionnaire. The initial observations were that all participants

| Level of compet ence | Assessment criteria | | |
|---|---|---|---|
| | *Understanding* | *Strategies, Reasoning, Procedures* | *Communication* |
| Low | The solution addresses none or a few mathematical components presented in the task. | The reasoning and strategy used do not help to solve the problem and there were many errors in mathematical procedures. | There is no use or inappropriate use of mathematical representations, terminology and notation. The explanation of the solution can't be understood. |
| Mediu m | The solution addresses some, but not all of the mathematical components presented in the task. | Some parts may be correct but a correct answer is not achieved. Could not completely carry out mathematical procedures. | There is some use of mathematical terminology, representation and notation. The explanation may not be clearly presented. |
| High | The solution addresses all of the components presented in the task and shows a deep understanding of the problem. | The strategy, mathematical reasoning and procedures used are correct and a correct answer is achieved. | There is effective use of mathematical terminology, notation and there is a clear explanation. |

Figure F.3: Mathematics assessment rubric (Adapted from [15] and [16])

carried out the tasks with enthusiasm and eagerness to learn using the new facilities. Generally, participants managed to log on the LMS and download the question paper within the first 15 minutes; however in 2 out of 4 sessions, the wireless network was either not working or very unstable, thus making the connection to the network difficult. Despite the technical challenges, students appeared very motivated throughout the experiment, as they worked in groups of 2 to 3 students. The topic of assessment was new to them and they collaborated in problem solving, showing each other how to do while referencing to their class notes. The experiments helped them to revise the course materials and work in groups towards a common goal. In

addition to collaboration on problem solving, they were also helping each other in finding the right tools on the iPad interface as shown in Figure F.4.

With reference to the correct answer-sheet from the lecturer, students assessed



Figure F.4: Students' collaboration

each other's work, and they were able to spot the mistakes and errors, then providing a feedback with detailed reasoning on the right procedures. For example in Figure F.5, a student points out that "the function is odd" and another one states that "Sin $n\pi = 0$ always", which explains why the given answer is wrong. This kind of feedback is helpful as a student mentioned: "it helped me because my classmates corrected my maths mistakes and showed me what I should have done, and also appreciated what I did well".

Further on, the mathematics assessment rubric was mostly used by the students to judge on the performance level, however in some cases, students preferred to use grades for the performance appraisal.

Figure F.6 illustrates the appreciation of performance, where one assessor judged the understanding, strategies, reasoning and procedures while another chose to give the grade of 4 out of 5 to judge on the "communication", since there is a "missing formulae". The level of details in the feedback shows a high level of student engagement and responsibility as well as the willingness to help their peers to improve on their work. Upon reception of the peer-feedback, the author observed participants going through the comments and cross-checking with the answers from the lecturer.

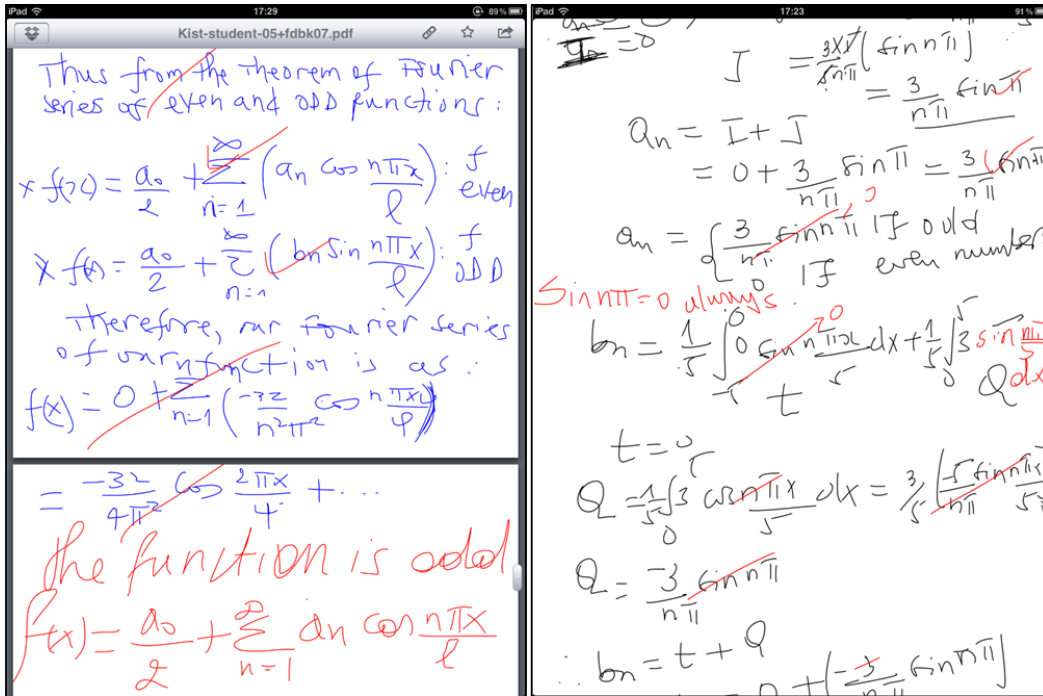It was noted that students realised their mistakes and they seemed encouraged
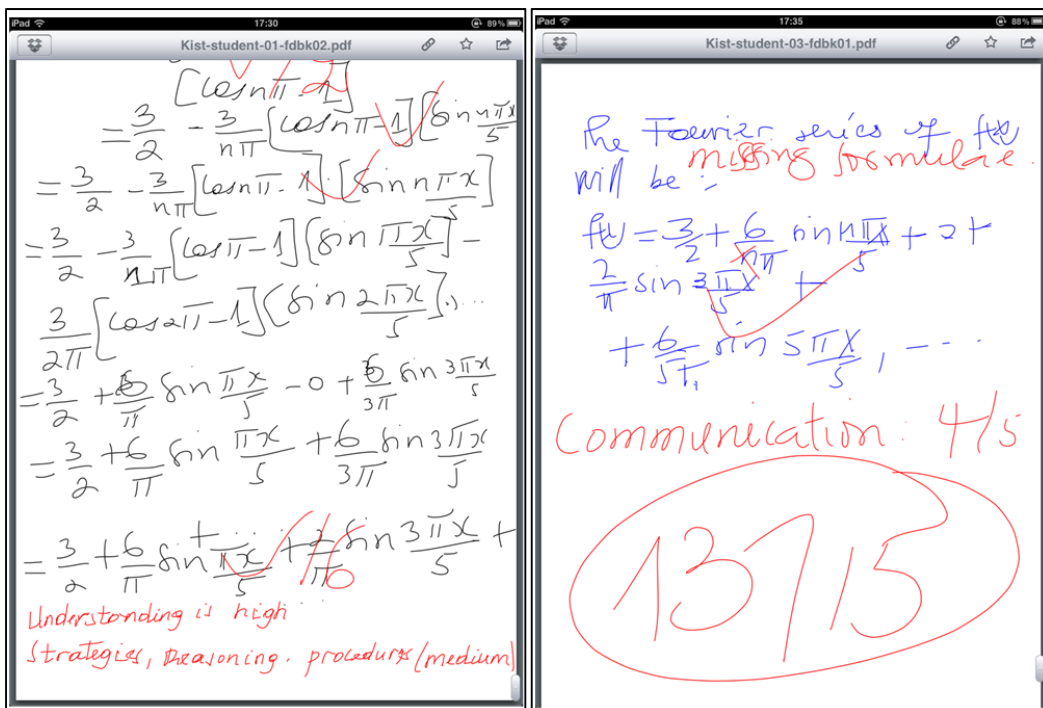
F

Figure F.5: Peer-feedback.

Figure F.6: Performance assessment in the P2PASS.

to work again on the related/similar exercises within the context of the P2PASS

in order to improve their performance. A participant said that one of the benefits of the P2PASS is "less stress since you know that your colleague will assess you, whereas marking by the teacher makes you nervous and you can't write all your ideas". It was also said that P2PASS "is good because you feel comfortable with your colleagues and it encourages competition among students". Participants also suggested that those who did well should explain their answers to others for them to learn several approaches to problem solving.

Subsequent to peer-to-peer assessement sessions, participants answered a sur-
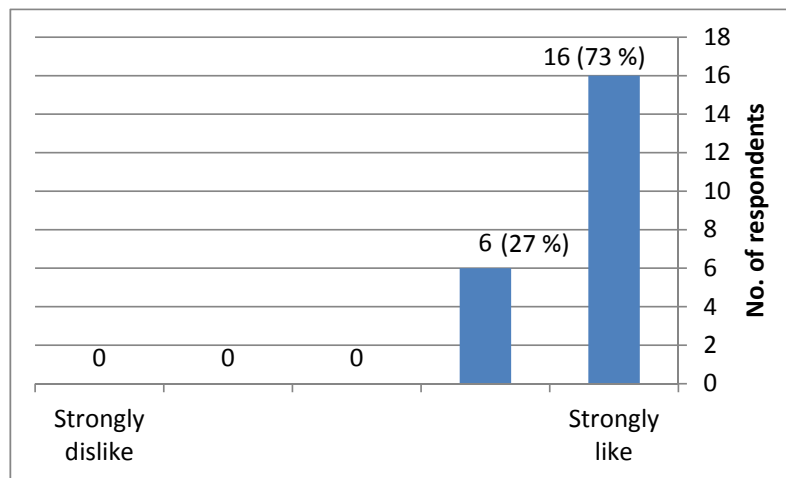


Figure F.7: Opinion on peer-assessment
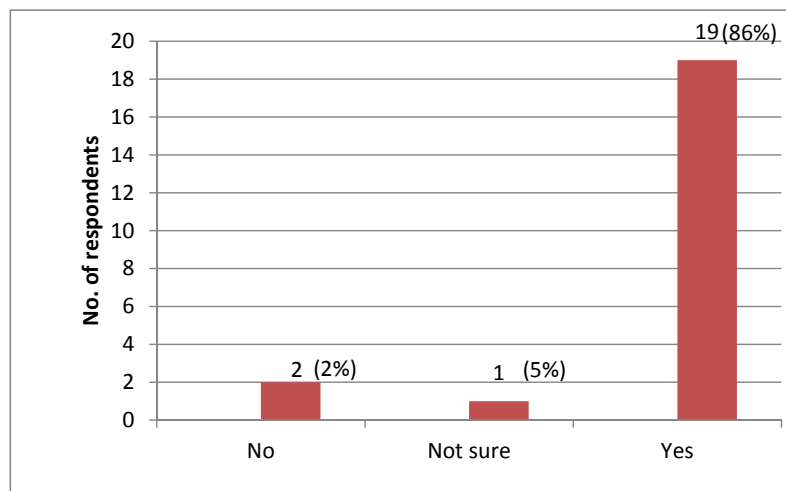


Figure F.8: Confident to provide a fair and responsible feedback

vey questionnaire. The students were very positive about peer-assessment as shown in Figure F.7, with 16 out of 22 participants (73%) who "Strongly like" it. The majority of participants (86%) also felt confident to provide a fair and responsible

feedback (in Figure F.8), and likewise the same number of participants expressed confidence to be able to receive a fair and meaningful peer-feedback as presented in Figure F.9.
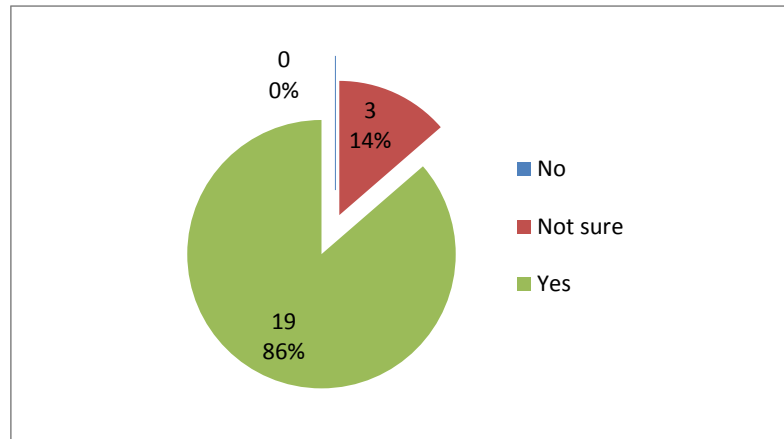


Figure F.9: Confident to receive a fair meaningful peer-feedback
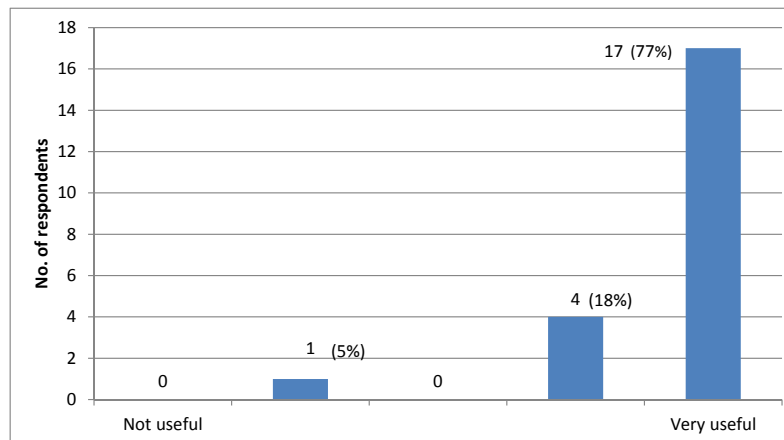


Figure F.10: Opinion on usefulness of peer-feedback

Regarding the usefulness of peer-feedback, Figure F.10 shows 17 students (77%) who replied that peer-feedback is very useful whereas 4 (18%) deemed it useful. This high level of perceived usefulness can explain why the students are very interested in peer-assessment. As the majority of participants mentioned, they are willing to take part in P2PASS because of the expected help from their peers, the opportunity to see how others solve the given problems and the ability to share what they know as a collective effort. The latter point supports our opinion that P2PASS promotes collaborative knowledge construction, as the students gather the information,

discuss in groups and agree on different approaches to solve the problem. On the other hand, the new technology in this study also encouraged students' participation, this being reflected on the students' opinion on the frequency of P2PASS shown in Figure F.11. Students suggested that P2PASS should take place every week (82% of the participants); however we believe that this is not only due to the perceived usefulness of peer-feedback, but also the excitement about the technology-supported learning. In fact, 14 participants (64%) mentioned technology in their answers on what they liked about the system (processes) used in P2PASS, with one of them stating: "I liked answering and making feedback using the pen of the iPad and share them online". Hence, we suggest that, P2PASS should be organised at least once every two weeks. Besides the usefulness, the system was also effective as shown in Figure F.12, where 13 (59%) and 8 (36%) participants spent up to 20 minutes and 40 minutes respectively on providing peer-feedback. The numbers are encouraging, considering that if every student was to provide up to three peer-feedbacks it would take between one and 2 hours for everyone to have their work assessed, whereas the teacher would spend much more time, if possible at all, to provide similar feedbacks to a large class of students (up to 300 students in some cases of engineering mathematics classes).
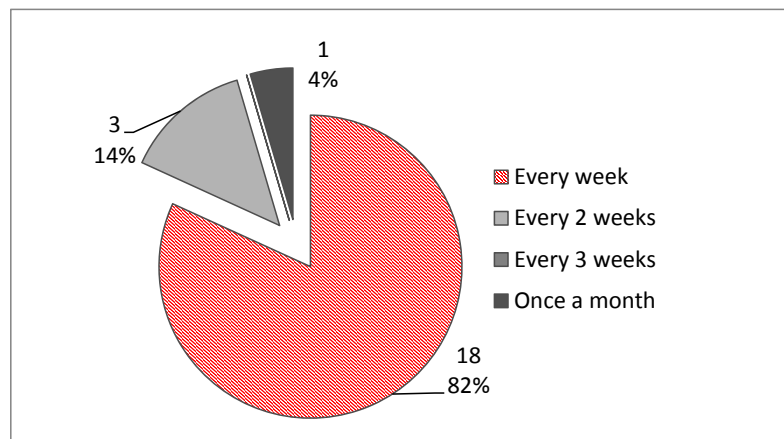


Figure F.11: Opinion on the frequency of feedback

In addition to the benefits of the technology involved in P2PASS, participants mentioned other motivational factors in providing peer-feedback, such as boosting the confidence for those who did well, being there for each other, seeing own weaknesses and the way to improve, getting used to competition, and the necessity to mark others accurately as they also anonymously mark your work, just to name a few.
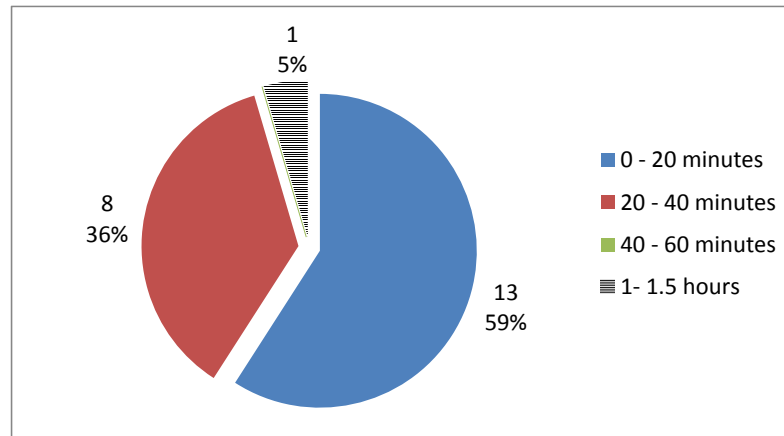
Figure F.12: Effectiveness (time spent on providing P2PASS)

The users' opinions on the easiness to provide feedback reflect some level of difficulty as shown in Figure F.13. This indicates the need to equip students with the necessary skills for authentic assessment, for instance to improve their ability to recognise any knowledge gaps as well as to understand the assessment rubric used for performance evaluation.
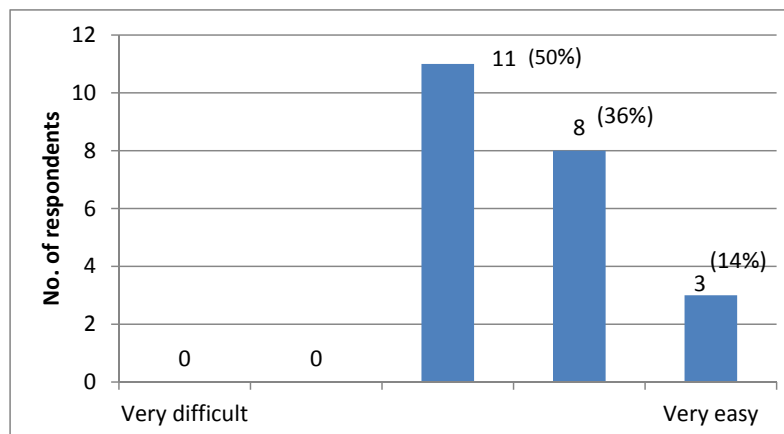


Figure F.13: Easiness to provide feedback

On the other hand however, the majority of participants were satisfied with the P2PASS (Figure F.14) as the system was easy to use and interesting as shown in Figure F.15 and Figure F.16 respectively.

The system used in this study was easy to learn since all participants were novices yet they managed to learn how to use it in a single session. It was also effective because apart from one participant who lost his work without saving it,
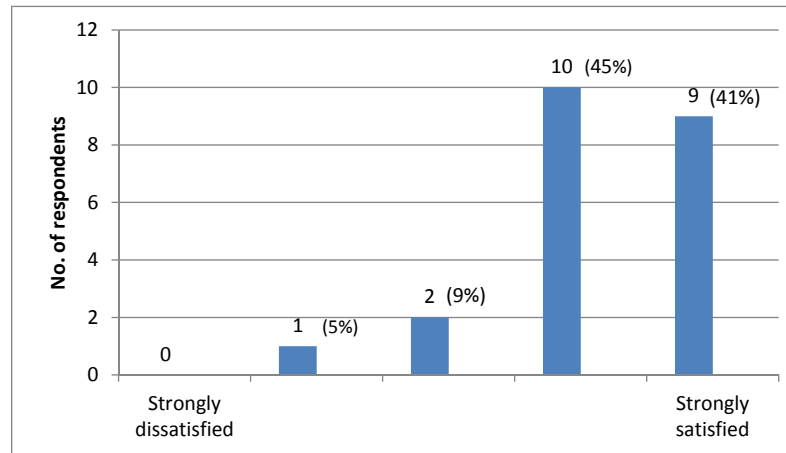
Figure F.14: Opinion on satisfaction with the P2PASS

everybody else completed all tasks. However, the system was not so intuitive; the users had often to ask the researcher (in addition to the written instructions) regarding the tools to edit, save or retrieve a file. There were also problems with the system interaction and recovery from errors (the user interface did not provide useful error messages for the user to understand how to recover from the errors and proceed with their tasks).
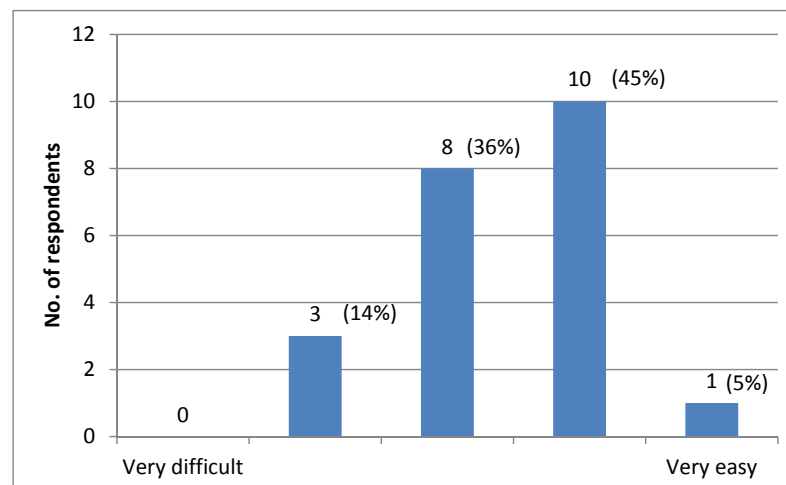


Figure F.15: Easiness to use the system

The mobile tablet technology allows users to directly and naturally write on the documents with their fingers, especially when they need to make a point at a particular location on a document, and this was put to good use while marking the mathematics papers. Unlike other forms of computer-mediated assessment, the assessor can give comments at the exact place where it's needed rather than the end of
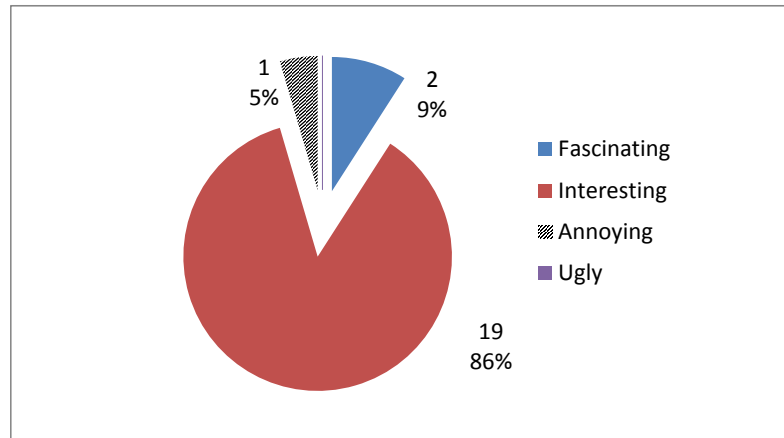
Figure F.16: Opinion on the system appearance and responsiveness

the document, thus enabling easy access for the reader. Using iPad in mathematics learning has an added value, as one of the students commented that "it helped so much, it enabled us write using pens -stylus- like we do on papers resolving maths problems". We argue that this is faster than using the mathematical editors (e.g. Latex editor) when the work needs to be shared online by the students. The participants also reiterated the benefits of the iPad mobility and portability as they would be able to take part in peer-feedback provision on their own pace, regardless of the time and location ( if there is Internet connectivity ).

### *B. Challenges and limitations*

The implementation of P2PASS is dependent on a good wireless connection (Wi-Fi) and a stable Internet connection. The experimental work was affected by the loss of Internet link which resulted in postponement of the P2PASS session in some cases. Furthermore, the university organisation today is not prepared to support the modern approach of P2PASS, because of the administrative and technical challenges.

The students' tasks in the study were limited to solving and marking only one mathematics question (the answer could fill up to 7 pages for some students) due to limited time. It was also not possible to carry out multiple sessions with the same participants in order to judge the impact of peer-feedback on their performance. Further on, the students found it challenging to get introduced to a new concept of learning plus the new technological approach and yet to be required at the same time to apply those to a new topic on their course. That seemed a lot to learn for them in a short time. The improvements can be made in terms of students' pre-

paredness, network infrastructure availability, and the usability aspects of the iPad applications for peer-assessment as well as the integration of formative assessment into the curriculum.

## V. Conclusions

iPad technology-supported formative assessment of a mathematics course was investigated. The study took place in a society where higher education, especially in engineering subjects, is very much considered as the best way to ensure a prosperous future. The access to information and communication technology is still very limited to the students' communities and every opportunity to experience new technology is regarded as an added value.

The social context in Rwanda is also such that there is a higher tendency of the people to collaboratively work towards reaching common goals in everyday life. Therefore, the students are very positive about collaborative learning. They responded very well to the new approach of technology-supported learning and expressed their desire to have the formative assessment implemented in their learning plan.

The study uncovered the students' potential to contribute to the construction of their knowledge and the capacity to fairly and objectively assess each other's progress. The students were motivated both by the expectation to receive the feedback and the opportunity to learn from their peers.

With the P2PASS, the students can answer the mathematics questions without feeling the stress of the teacher's judgment; they are free to try more methods and procedures. There is also a strong indication of possible improvements in student engagement in learning because the peer-feedback encourages more revising of the study materials as well as the development of a mental ability to compare a student's performance against the reference performance level or goal. Current iPad applications can serve well the purpose of P2PASS, but further work can be done to design and implement a more integrated solution to improve the user experience. Additionally, a similar study can be undertaken over a longer period of time to allow a comparative study on the mastery of the subject and the performance between two groups of students, one in a traditional learning setting and another one with regular technology-supported peer-feedback.

F

**REFERENCES**

[1] E. Z. F. Liu, "Peer and self assessment for mobile learning", in *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Lugano, Switzerland, 2004, pp. 4370-4372.

[2] N. P. Morris, "Podcasts and mobile assessment enhance student learning experience and academic performance", *Bioscience education*, vol. 16, Dec. 2010.

[3] C. Chen, "The implementation and evaluation of a mobile self- and peer-assessment system", *Comput. Educ.*, vol. 55, pp. 229-236, Jan. 2010.

[4] D. R. Sadler, "Formative assessment and the design of instructional systems", *Instructional Science*, vol. 18, pp. 119-144, Jun. 1989.

[5] K. Topping, "Peer Assessment Between Students in Colleges and Universities", *Review of Educational Research*, vol. 68, No. 3, pp. 249-276, 1998.

[6] M. L. Wen and C.-C. Tsai, "Online peer assessment in an inservice science and mathematics teacher education course", *Teaching in Higher Education*, vol. 13, No.1, pp. 55-67, 2008.

[7] P. Black and D. Wiliam, "Assessment and classroom learning", *Assessment in Education: Principles, Policy & Practice*, vol. 5, No.1, pp. 7-74, 1998.

[8] K. E. Dunn and S. W. Mulvenon, "A critical review of research on formative assessment: The limited scientific evidence of the impact of formative assessment in education", *Practical Assessment, Research & Evaluation*, vol. 14, No. 7, pp. 1-11, Mar. 2009.

[9] C. Aoun, "Peer-assessment and learning outcomes : product deficiency or process defectiveness?". In *in Proceedings of the 34th International Association for Educational Assessment (IAEA) Annual Conference*, Cambridge, UK, 2008.

[10] P. Nokelainen, "An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students", *Educational Technology & Society*, vol. 9, No.2, pp. 178-197, Apr.2006.

[11] J. Nielsen, "Evaluating hypertext usability", in *Designing hypermedia for learning*, ed: Springer-Verlag, 1990, pp. 147-168.

[12] J. S. Dumas and J. C. Redish, *A practical guide to usability testing*, Oregon, USA: Intellect Books, 1999.

[13] J. Nielsen, *Usability Engineering*, Boston, USA: Academic press, 1993.

[14] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly*, vol. 13, pp. 319-340, Sept. 1989.

[15] Exemplars, "Classic Math Rubric", 2006. http://www.exemplars.com/ assets/files/math_rubric.pdf. (Access date: 21 May, 2012).

[16] G. Egodawatte, "A rubric to self-assess and peer-assess mathematical problem solving tasks of college students", *Acta Didactica Napocensia*, vol. 3, no.1, pp. 75-88, Mar. 2010.

F

# Appendix G

# Paper VI

**Title:**    Developing a Formative Assessment System for Mathematics Using Mobile Technology: A student Centred Approach

**Authors:**    **Ghislain Maurice Norbert Isabwe** and Frank Reichert

**Affiliation:**    University of Agder, Faculty of Engineering and Science, Jon Lilletuns vei 9, 4879 Grimstad, Norway

**Published in:**    *Proceedings of IEEE International Conference on Education & E-Learning Innovations ICEELI' 2012*, Sousse, Tunisia, July 2012.

G

G

# Developing a Formative Assessment System For Mathematics Using Mobile Technology: A Student Centred Approach

Ghislain Maurice Norbert Isabwe, Frank Reichert

Faculty of Engineering and Science, University of Agder

Jon Lilletuns vei 9, 4879 Grimstad, Norway

E-mails: {maurice.isabwe, frank.reichert}@uia.no

*Abstract* — **The success of mobile technology for learning tools depends not only on the technical design aspects but also on pedagogical issues. Students' involvement in designing the tools is one of the key factors for their engagement in technology supported learning. Students should be actively involved in developing innovative solutions which are likely to improve their skills as well as their performance. In this study work, the students participated in iterative design processes of a mobile tablet based peer-to-peer assessment system (P2PASS) for mathematics, and in real life deployment on a mathematics course. The paper reports on two major concepts: the user centred design in practice and the pedagogical implications of formative assessment in mathematics education at university level. The improvements on the usability aspects of the P2PASS system are discussed together with the potential role that such a system could play in collaborative learning of mathematics.**

*Keywords*—User centered design; mobile learning; assessment.

G

## I. INTRODUCTION

Mathematics is a core subject in engineering education, and students who struggle with mathematics are more likely to fail in other subjects too. In fact, most of engineering subjects heavily rely on mathematics in one way or another. Consequently, it is not unusual to find large mathematics classes in the faculty of engineering at many universities. Large classes come with a big challenge to the teaching staff to interact with all students, and there is a risk of limited control over the students' progress during the course of study. Thus, there should be a possibility to help the students to become less dependent on the teacher, and facilitate opportunities for constructing the new knowledge together based on their existing skills. The students could build upon individual experiences to expand their body of knowledge through negotiations as well as social interactions among themselves.

The authors believe that students have different learning abilities but each and everyone has a potential to perform better if equipped with the right tools. It is our understanding that the right tools are not only the material equipment but also the teaching and learning methods. Hence, there is a need to establish a right balance between the two categories. In fact, there is a group of students who do not do so well because they need more interaction with others in the learning scenario; but there are still those who fail because of the lack of motivation and/or interest in a given subject (mathematics in this case).

This study intends to contribute a possible solution which can potentially enhance the students' learning of mathematics. Founded on the social constructivist theory of learning [1][2], the solution enables students to work together towards achieving a common goal. The key concept is that students perform regular assessments of their learning progress, whereby students assess each other's work under the explicit guidelines of the teacher. It is argued that the students get more engaged and pay extra effort to learn more while they assess their colleagues' work.

Furthermore, of our interest are the tools chosen to support such a learning scenario. Hereby, consideration is given to a technology supported learning tool using mobile tablet computers and web technologies. The prospects of using mobile technology in learning environments are on the rise given the promises to allow ubiquitous flexible learning. However, mobile learning in mathematics and related subjects comes with challenges of its own because of the very nature of the mathematical notations. It is neither easy nor practical to represent mathematical objects and ideas using the keyboard/ keypad on a feature mobile phone or a smart phone (up to 4 inches screen size). This challenge is not limited to the mobile phones but also the Laptop computers with a full size keyboard. It is still not efficient for stu-

dents to use any formula editors to solve the mathematical problems and plot some graphs. This study argues that a mobile tablet can provide a better user interface, where the students can naturally write mathematical symbols, plot graphs and correct their colleagues' work as it is done like using pen and paper.

The aim of this article is to present what happens when students are involved in developing a mobile technology based learning system. The students' behavior is studied as they get engaged in a form of formative assessment designed for mathematics. Proposed is a solution that was designed with the students as co-designers. Software design, as any other product design, requires the involvement of the users from the early stages of development to ensure that the end product will serve the purpose. The usability testing is carried out to find out design problems so that they can be progressively addressed throughout the design process. The authors argue that when a representative sample of students contribute in the solution design, more students are likely to use and adopt the system in their learning. It is noted that in addition to the students, this study also considered inputs from three professors who teach mathematics at the undergraduate level.

In the next section, the state of art in mobile learning and mathematics peer assessment is presented. Then the article continues, in Section 3, with a description of the user centred design methods that are used in this study. Section 4 contains the results of the investigation and discussions as well. Finally, a conclusion and the future directions are given in Section 5.

## II. STATE-OF-THE-ART

### A. *Mobile learning in Mathematics*

Students and teachers need mobility and flexibility, both of which can be achieved with mobile technologies. Tella [3] presented the phenomenon of "M-Learning" (also commonly known as "mobile learning") referring to the use of mobile technologies to study and communicate. The term "mobile learning" however, can mean different things depending on the context of use. In order to avoid any ambiguities, in this article, mobile learning refers to a learning situation in which the student makes use of one or many mobile device(s) to access the learning material (content), to edit the learning material and to carry out any other activities intended to enabling the knowledge and skills acquisition in the context of a subject of study.

Mobile learning applications for learning mathematics are being developed in various settings, from simple arithmetic operations to advanced topics such as statistics and calculus. Robledo-Rella et al. [4] developed mobile learning resources to

increase the learning literacy of the $5^{th}$ grade in Mathematics. The authors found that the mobile learning resources had a positive impact on the students' performance in terms of the ability to solve the mathematics problems. The literature suggests that mobile learning can help to engage students in learning mathematics, through scenarios that enable authentic context and solving real world problems [5][6].

### B. Peer assessment in Mathematics

"Peer assessment" is a process that can be used to monitor the students' progress with the intention of helping them to progressively meet their learning goals. In a peer assessment process, the students are involved in assessing each other's work and providing constructive feedback.

In a previous study [7], we found that the students would be interested in getting regular feedback from their colleagues. Further on, we have worked with students to understand their requirements and attitudes towards mobile technology supported peer-to-peer assessment in mathematics courses [8] . The concept of "peer-to-peer assessment" originates from the "peer-to-peer" model used in communications networks, where each entity works both as a server and a client for others. In the same way, in "P2PASS", each student assesses and provides feedback on the work of other students and vice versa. The study in [8] shows that mobile tablet technology can greatly contribute to the integration of peer-to-peer assessment into mathematics education; and providing peer-feedback is a practical approach to formative assessment. In a related study, students showed a potential to objectively assess mathematics, and the importance of collaboration in problem solving was observed [9].

P2PASS in mathematics exhibit several challenges related to the process itself, especially concerning the objectivity in assessment. As students may not be able to qualitatively assess mathematics, the assessment rubrics and a sample of correct answers are given to them for reference. Students should be able to understand the assessment criteria but also have usable tools for the purpose. There is a need for special tools to handle mathematical expressions. Our studies have explored a mobile tablet technology supported solution, with facilities to solve the mathematics problems on the tablet computer. The students were able to receive immediate feedback on their work through a learning management system. On the other hand, the tools used in those early studies were not integrated and the students faced technical usability problems.

### III. METHODS

This work follows the empirical research practices, with the knowledge being derived as a result of observations and experiments. The key players here are the students: their inputs influence the design decisions regarding the peer-to-peer assessment tool as well as the implementation and evaluation.

A user centered design approach ensures that the product is designed with an understanding of the needs of the intended users, in this case the students. Hence, the students were involved in this work as co-designers:

- Preliminary interviews were carried out to understand the students' perceptions about the peer-to-peer assessment concept. The students also expressed their views about a potential mobile technology supported tool. A total of 12 students were interviewed.

- 2 Computer science students were hired for software coding tasks. They also provided input for the user interface designs.

- 10 students participated in usability studies, and they were involved at all stages of design until and after a working prototype was realized. The participants comprised of 3 females and 7 male students, between 18 and 30 years of age. The sample target group was undergraduate engineering students taking at least one mathematics course at the time of the study.

The researchers in this study recruited students participants using messages sent through the learning management system as well as direct contacts to random students. All of the test users voluntarily took part in the experiments. Even though the computer science students who did the software coding tasks were also volunteers, they had to get a recommendation /approval from their study coordinator.

The goal of a usability testing is to identify the usability problems of the system in a real life scenario. Multiple user studies are carried out, throughout the design cycle, from early concepts to a working prototype as shown in Figure G.1. Generally, it is assumed that a substantially large number of users would provide more information to the design team. However, in this study there are resource constraints because, one, the research project is undertaken by the students who must complete their work in a short term; and two the financial implications of working with many test users.
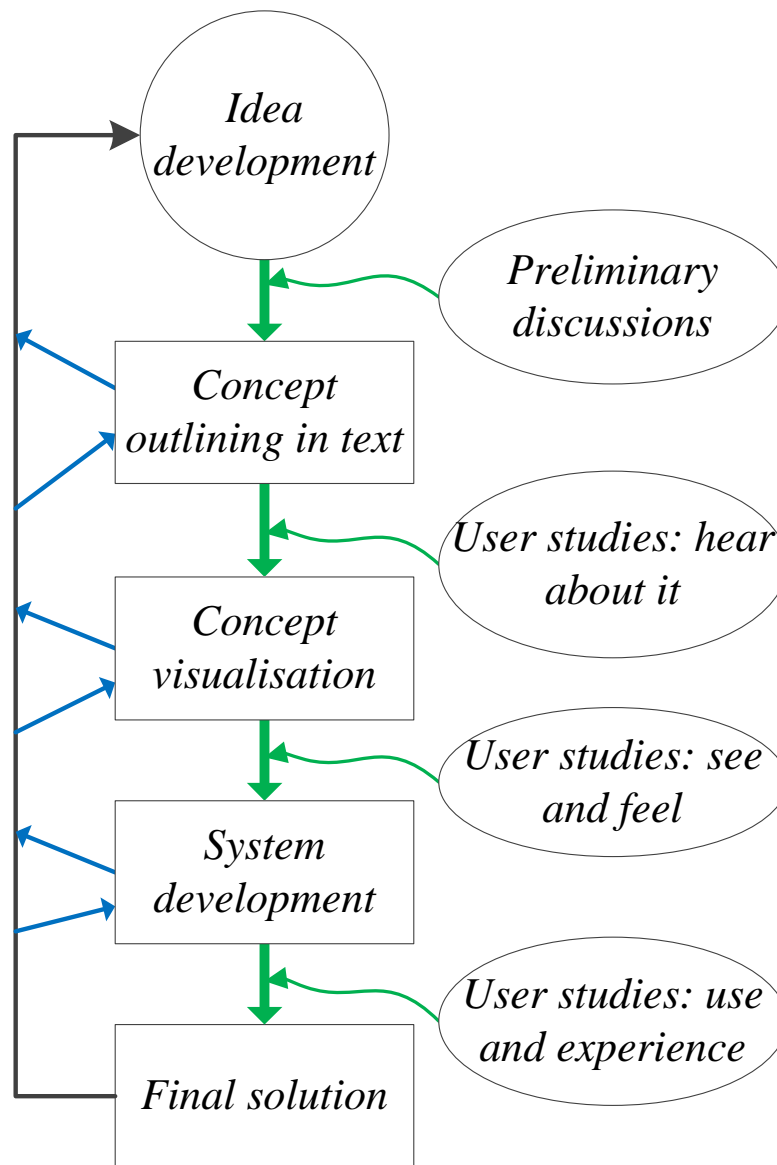
G

G



Figure G.1: Iterative design process

The sample size in user studies has been widely debated, in some cases with indications that almost all significant problems are likely to be found with the first three users [10]. In fact, an empirical evidence was presented suggesting that up to 80% of the usability problems are detected with four to five users [11]. It was further argued that increasing the number of users in the same test is not likely to bring new information; therefore it would be more effective to iteratively carry out many tests with a few users [12], rather than a few tests with many users.

The design in this work was an iterative cycle with designs being constantly evaluated against the users' requirements following the processes shown in Figure

G.2. The usability testing is part of an iterative test-and-design cycle. The testing consisted of cognitive walkthrough sessions, during which the participants were given a scenario with well-defined tasks to complete. Using the "Think aloud" method, test users were encouraged to communicate their experience while they perform the given tasks. They were also required to note down on a piece of paper any problems that they may encounter. The think aloud method is one of the techniques of choice in usability testing [13], because the users can externalize their views and thoughts while they are performing the given task(s). This technique gives opportunities to the evaluator or researcher to make sense of what is going on in the minds of the test users; regarding how they feel about the interaction with the system under test. The information collected through this method was complemented by the researcher's observations and unstructured interviews at the end of a test session. Additionally, participants completed web based surveys comprising of attitude questions on a 5-point Likert scale as well as open ended questions.

All of the user studies took place in a controlled environment, with audio and
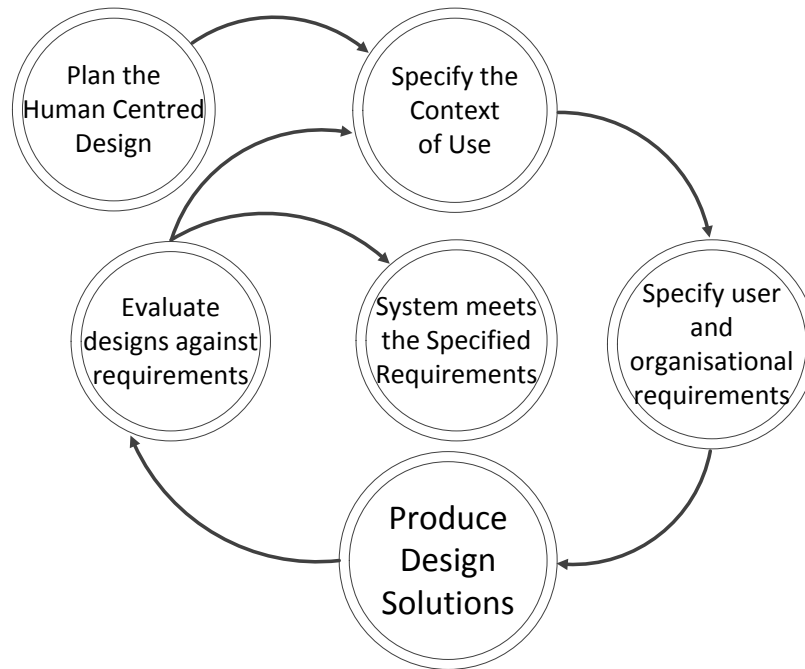


Figure G.2: User Centered Design Processes (Based on ISO 13407).

video recording. The usability testing was carried out in three major steps:

- Low fidelity test: designs were evaluated using paper mockups. The users were asked to perform tasks on mockup interfaces created using an open source graphical user interface (GUI) prototyping tool, the Evolus Pencil [14].

- Medium fidelity test: this is a second stage of testing with dummy user interfaces. The prototype GUI was mapped into a slide presentation, in such a way that each task button would open a link to a corresponding slide.

- High fidelity tests: a series of user studies were undertaken to find usability problems on a fully working prototype.

## IV. RESULTS

### A. *Peer-to-peer assessment system for mathematics*

During the first two months of the study, the user requirements were defined. The peer-to-peer assessment process shown in Figure G.3 was devised with inputs from students and three teachers of mathematics at the undergraduate level.

It is understood that the teacher provides the assignment questions together with examples of the solutions that are revealed to the students when they assess each other's work. Obviously, the solutions are not shown to students until they have finished answering the questions on their own.

Based on the user and organizational requirements, an application, called "The Agder Peer Assessment System (A-PASS)", was developed. A-PASS is a mobile technology supported solution that can allow users to write mathematical expressions on the mobile tablet in the same way as pen and paper. A-PASS provides the opportunities of a step by step assessment and feedback on the mathematics answer rather than assessing the final answer only. It also has a feature to provide an overall written feedback. The solution is a web application that considered the Apple iPad mobile tablet computer as the end user platform. The software is based on Microsoft .Net architecture with C#, SQL database and HTML5/CSS3. The application is hosted on a Windows Server 2008, with Internet Information Services (IIS) 7.5.

A-PASS has two main interfaces: the students' interface and the teachers' interface. The students' interface enables them to solve the assignments, to assess and provide feedback to each other, to view individual feedback and to edit personal details. The teachers' interface is for managing the assignments as well as monitoring the students' progress. The illustration in Figure G.4 shows an example of a student's interface, where a student named "Teta Annie" is providing assessment and feedback on an anonymous student's work. The user interface has a possibility to write on top of the answer sheet for marking. This is expected to help the student see where he/she has made a mistake in the answer. The assessor can also write
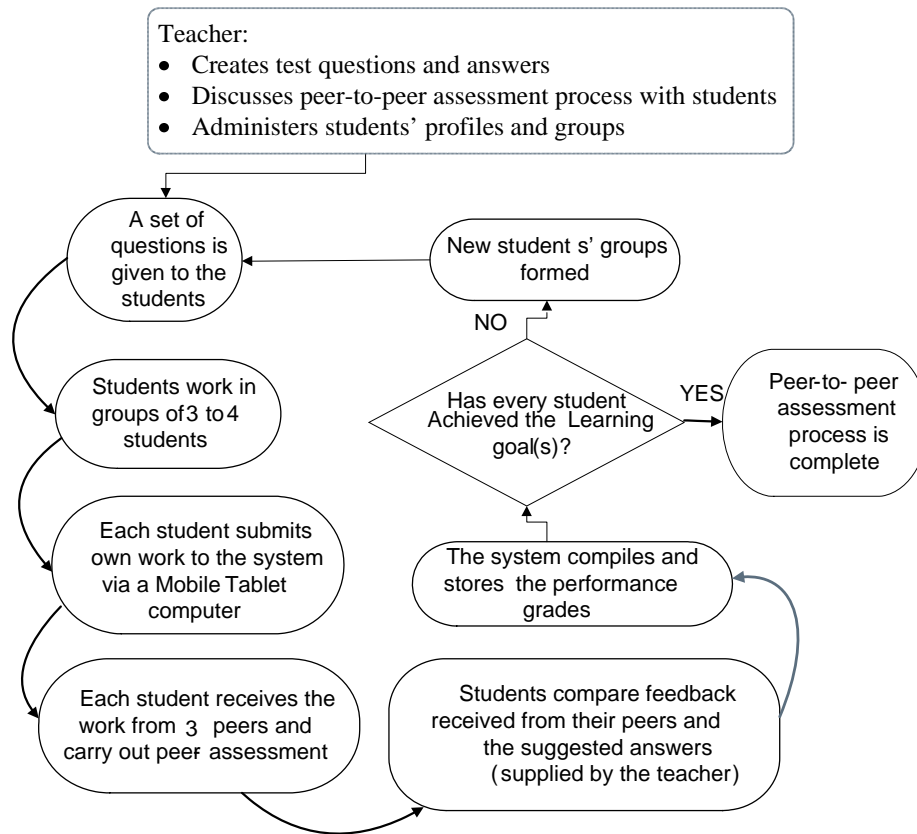
Teacher:
- Creates test questions and answers
- Discusses peer-to-peer assessment process with students
- Administers students' profiles and groups

A set of questions is given to the students

New student s' groups formed

Students work in groups of 3 to 4 students

Has every student Achieved the Learning goal(s)?

NO

YES

Peer-to- peer assessment process is complete

Each student submits own work to the system via a Mobile Tablet computer

The system compiles and stores the performance grades

Each student receives the work from 3 peers and carry out peer assessment

Students compare feedback received from their peers and the suggested answers (supplied by the teacher)

Figure G.3: Peer-to-peer assessment process.

what is missing (like the brackets shown in the equation). On the right side of the interface, the marker can also provide a detailed feedback by typing and a performance grade as well (Low, Medium, High). An assessment rubric is provided under the "Assessment Criteria" tab, with details of performance grades. The assessor can access all tools on one single page, hence avoiding the page loading delays or unnecessary steps between multiple pages. In case of uncertainty, the assessor can check on the right answer from the teacher by simply clicking on the "Solution" button. This interface, although not perfect, is a result of many design iterations following the user studies.

A-PASS is designed to support collaborative learning. The students work in groups, and each student can receive up to three reviews (feedback) from the colleagues. In Figure G.5, a student has chosen to view feedback from the first reviewer; he could also see the feedback from others including the teacher (optional). There is also a provision for complaining should someone try to abuse the system
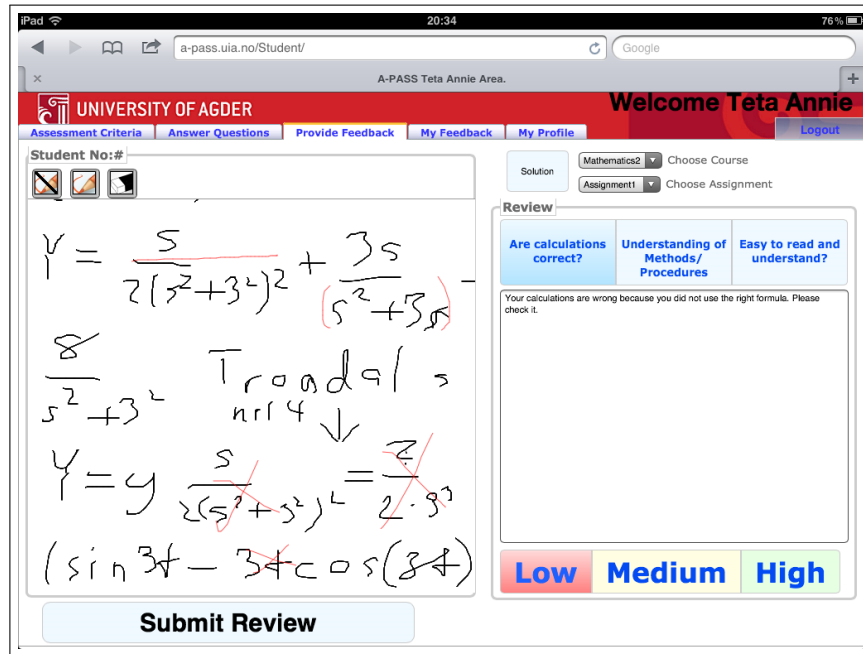
Figure G.4: Student interface for providing feedback.

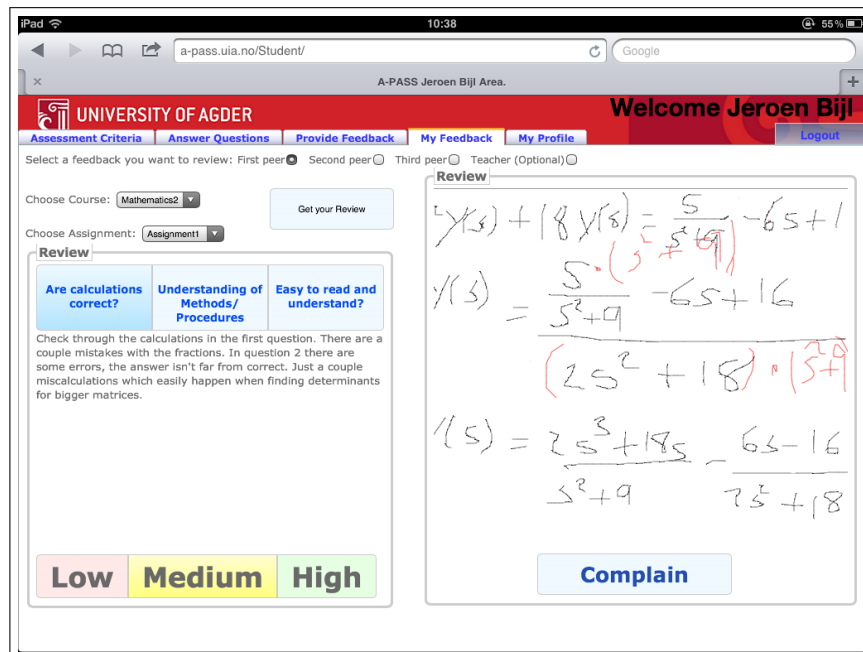("cyber bullying") or unfairly give a negative feedback.



Figure G.5: Student interface to view own feedback.

The teacher can create a course in order to give assignment to the students. When the students register, they have to choose a course among other things, and

the system places them into students' groups for them to work together. Initially, the groups are randomly created, but on successive rounds the students are grouped with consideration to their previous performances. The assignments are uploaded to the system either as PDF file or through the system interface which supports a mathematics engine (MathJax) in the browser. The teacher must set the start and end time of the assignment for the students to know when they can assess each other's work. Figure G.6 shows an interface for managing the assignments.
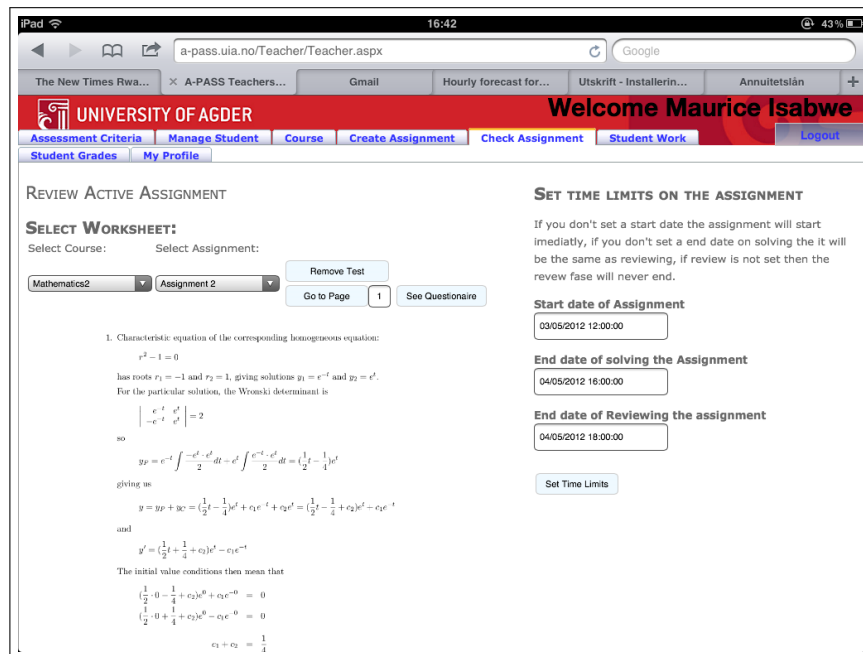


Figure G.6: Teacher's interface to manage the assignments.

The teacher should be able to monitor the performance in order to help students to achieve the learning goals.

The interface shown in Figure G.7 is for the teacher to see the student's answers and the review from other students. This information is crucial for the teacher to see any knowledge gaps but also to ensure that the student generated feedbacks are fair and meaningful.

### B. Usability tests

Usability testing aims at discovering the users' attitudes and perceptions towards the system, for the design team to make a more usable system. Several usability tests were carried out, but this paper reports on the last two tests, "A" and "B" as shown in Table 1 (Figure G.8). In each test, five participants were asked to answer

Figure G.7: Teacher's view of the student feedback.

questions related to usability criteria shown in the table. During the second test, the same participants were asked the same usability questions but the system had been improved based on the results of the test "A". The tasks given in test "A" were to solve very basic algebra questions whereas in test "B" more complex questions on Laplace transformations were used.

| Usability criteria | Usability test | User 1 | User 2 | User 3 | User 4 | User 5 | Average |
|---|---|---|---|---|---|---|---|
| Easiness of using | A | 5 | 2 | 1 | 4 | 2 | 2,8 |
| | B | 3 | 4 | 4 | 5 | 4 | 4 |
| Effectiveness (Ability to complete the tasks) | A | Yes | Yes | No | Yes | Yes | |
| | B | Yes | Yes | Yes | Yes | Yes | |
| Sytem appearance | A | 5 | 3 | 5 | 4 | 5 | 4,4 |
| | B | 4 | 4 | 4 | 5 | 2 | 3,8 |
| Ability to recover from the errors | A | Yes | Yes | No | Yes | No | |
| | B | Yes | Yes | Yes | Yes | Yes | |
| Easiness of learning | A | 5 | 4 | 4 | 2 | 2 | 3,4 |
| | B | 4 | 4 | 4 | 4 | 4 | 4 |

Figure G.8: Technical usability test results.

Understandably, the second test would require the users to write longer mathematical expressions, which may need navigating between multiple answer pages. This affected the participants' opinion on the system appearance in test "B" as shown in Figure G.9. In addition to that, the cognitive load increases as the mathematics questions get tougher, hence reducing the users' resources that would otherwise be used to recall or recognize the system functionalities.

The participants to the final usability test also answered pedagogical usability related questions, designed with reference to the work of Hadjerrouit [15] and Nokelainen [16].

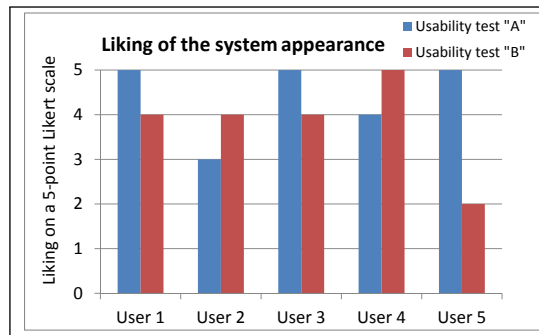The results in Figure G.11 suggest that the students can see pedagogical benefits



Figure G.9: Students' opinions on the system appearance.

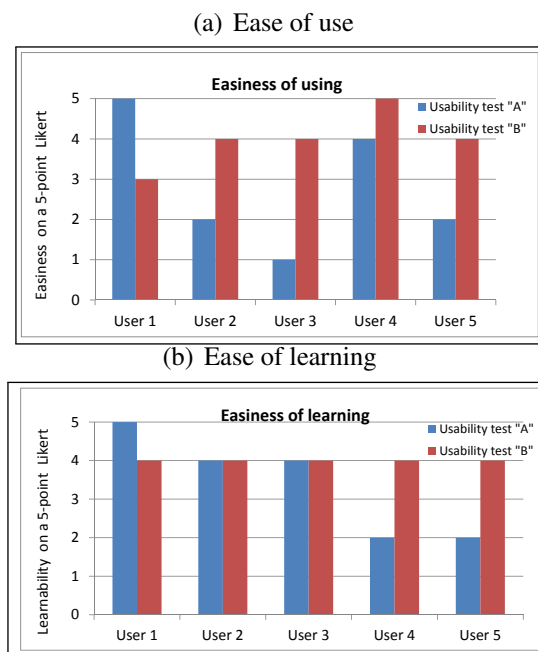(a) Ease of use



(b) Ease of learning



Figure G.10: Students' opinions on the ease of use and learning.

of peer-to-peer assessment. It is noted though, that these are only early indications. There is a limited evidence, since most of the values are within the range of 3 to 4 on Likert scale.

Consideration is given to the small sample size, because even a change in opinion by one participant has a big impact on the average. Although it is too early to firmly confirm that P2PASS has enhanced students' learning, it is clear that the students were given more opportunities to discuss and negotiate the approaches
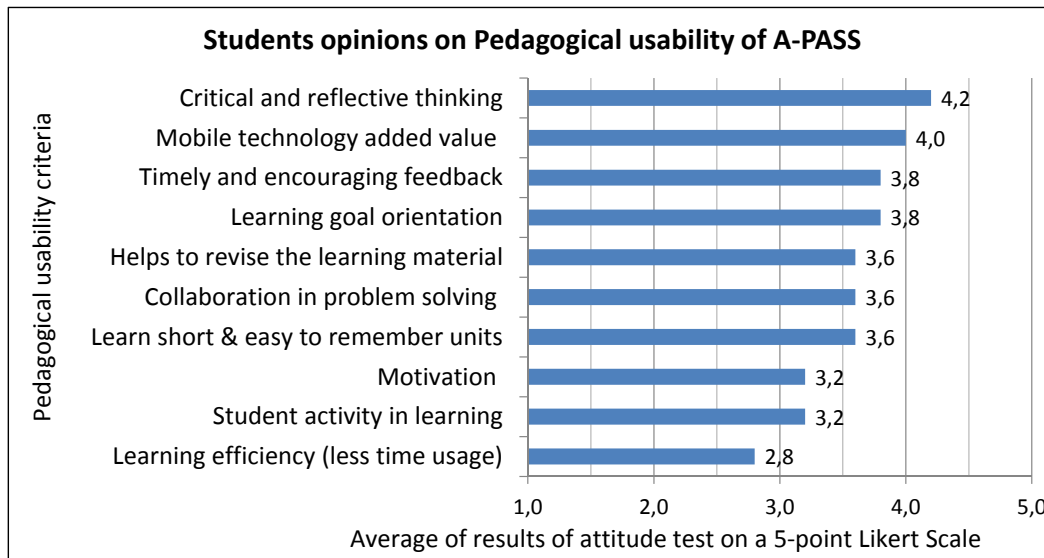
Figure G.11: Students' opinions on Pedagogical usability of A-PASS.

to problem solving. The students were also observed consulting their class notes, mathematics textbooks and websites, which increased their exposure to the learning material. The peer-feedback helped the students to see their weaknesses so that they can make necessary adjustments to bridge the knowledge gap.

## IV. CONCLUSIONS

This article presents the findings of a study on the development of a modern formative assessment system for mathematics at the university level. The involvement of students at all stages of the design cycle has resulted in a promising assessment system with enhanced user experience. Additionally, the students confirmed the perceived usefulness of the system and the pedagogical implications.

The system was designed as a proof of concept where the iPad was specifically targeted; hence there might be a need to make minor adjustments to ensure the best user experience on other platforms such as Android based systems. It is noted that this system has also been satisfactorily tested across multiple web browsers on the Personal Computer (PC). However it may be challenging to write the mathematical expressions using a PC mouse. A touch screen interface or a tablet pad may be required.

A-PASS is a step further towards a mobile tablet technology based peer assessment system for mathematics; however this study found challenges that should be addressed in order to make the students fully benefit from the system.

On the technical side, there is a need for sufficient resources to handle multi-

media files processing. It was observed that sometimes there are loading delays on the web pages and the cache memory on the iPad is saturated quite easily. The user experience is affected by the responsiveness of the web based system in a sense that the user needs to often perform the page refresh in order to accomplish a desired task. In addition to the lack of resources, the size of the tablet also matters because the users are used to writing mathematics on an A4 size sheet, and in this case they have to use a smaller interface. It may take some time for the users to familiarize themselves with the interface. There is also the price tag that comes with the tablet computers, but probably they will be more affordable as the technology matures.

From a pedagogical point of view, the study uncovered a lack of awareness for both the teaching staff and the students. The concept of peer assessment in mathematics is new at the faculty, let alone the use of iPad for learning mathematics. Hence, there would be need for changes in the teaching and learning methods. Students participation in the study was affected by other study priorities, in the sense that some students did not complete all the peer-assessment tasks in due time. Perhaps there should be incentives to make students more involved in such tasks.

G

**REFERENCES**

[1] B. Davis and D. Sumara, "Constructivist discourses and the field of education: Problems and possibilities," *Educational Theory*, vol. 52, pp. 409-428, 2002.

[2] B. Hand, D. F. Treagust, and K. Vance, "Student perceptions of the social constructivist classroom," *Science Education*, vol. 81, pp. 561-575, 1997.

[3] S. Tella, "M-Learning-Cybertextual Traveling or a Herald of Post-Modern Education,"in *Mobile Learning*, H. Kynaslahti and P. Seppala, Eds., ed Finland: Edita Publishing Inc., 2003, pp. 7-21.

[4] V. Robledo-Rella, G. Aguilar, S. Shea, R. Prez-Novelo, E. Ortega, J. C. Olmedo, J. Noguez, E. Tams, and P. Toiminen, "Design and evaluation of mobile learning resources in mathematics for public elementary schools in Mexico", in *Proceedings of IADIS International conference mobile learning 2012*, Berlin, Germany, 2012, pp. 51-58.

[5] M. Wijers, V. Jonker, and K. Kerstens, "MobileMath: the Phone, the Game and the Math," in *European Conference on Game Based Learning*, Barcelona, Spain, 2008, pp. 507-516.

[6] A. Alexander, K. P. Blair, S. Goldman, O. Jimenez, M. Nakaue, R. Pea, and A. Russell, "Go Math! How Research Anchors New Mobile Learning En-

vironments," in *Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE2010)*, 6th IEEE International Conference on, Kaohsiung, Taiwan, 2010, pp. 57-64.

[7]   G. M. N. Isabwe, M. Carlsen, H. Øysæd, and F. Reichert, "On the Mobile Technology Enabled Peer-Evaluation: A User Centric Approach," in *The 7th Annual International Conference on Computing and ICT Research (ICCIR11)*, Kampala, Uganda, 2011, pp. 272 - 285.

[8]   G. M. N. Isabwe, F. Reichert, and S. O. Nyberg, "Towards integrating technology supported peer-to-peer assessments into mathematics education: Experiences with iPad mobile tablet technology," in *Computer Supported Education (CSEDU 2012)*, Porto, Portugal, 2012, pp. 119 - 125.

[9]   G. M. N. Isabwe, "Investigating the usability of iPad mobile tablet in formative assessment of a mathematics course," in *International Conference on Information Society (i-Society 2012)*, London, UK, 2012.

[10]  S. Krug, Don't make me think! A common sense approach to web usability, 2 ed. Berkeley, CA: New Riders Publishing, 2006.

[11]  R. A. Virzi, "Refining the test phase of usability evaluation: how many subjects is enough?," *Hum. Factors*, vol. 34, pp. 457-468, 1992.

[12]  C. W. Turner, J. R. Lewis, and J. Nielsen, "Determining usability test sample size," *International Encyclopedia of Ergonomics and Human Factors*, vol. 3, pp. 3084-3088, 2006.

[13]  S. McDonald, H. M. Edwards, and Z. Tingting, "Exploring Think-Alouds in Usability Testing: An International Survey," *Professional Communication*, IEEE Transactions on, vol. 55, pp. 2-19, 2012.

[14]  D. T. An and N. T. Døng, "Evolus Pencil," 1.2 ed: Evolution Solutions Co., 2009.

[15]  S. Hadjerrouit, "A Conceptual Framework for Using and Evaluating Web-Based Learning Resources in School Education," *Journal of Information Technology Education*, vol. 9, pp. 53-79, 2010.

[16]  P. Nokelainen, "An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students," *Educational Technology & Society*, vol. 9, pp. 178-197, 2006.