Exploring The Impact Of Configuration And Mode Of Input On Group Dynamics In Computing

FOSTER, CHRISTOPHER,ROSS

Exploring The Impact Of Configuration And Mode Of Input On Group Dynamics In Computing

Christopher Ross Foster

A thesis presented for the degree of
Doctor of Philosophy

Technology Enhanced Learning Research Group
School of Engineering and Computing Sciences
University of Durham

March 2011

Abstract

Objectives*:* Large displays and new technologies for interacting with computers offer a rich area for the development of new tools to facilitate collaborative concept mapping activities. In this thesis, WiiConcept is described as a tool designed to allow the use of multiple WiiRemotes for the collaborative creation of concept maps, with and without gestures. Subsequent investigation of participants' use of the system considers the effect of single and multiple input streams when using the software with and without gestures and the impact upon group concept mapping process outcomes and interactions when using a large display.
Methods: Data is presented from an exploratory study of twenty two students who have used the tool. Half of the pairs used two WiiRemotes, while the remainder used one WiiRemote. All pairs created one map without gestures and one map with gestures. Data about their maps, interactions and responses to the tool were collected.
Results: Analysis of coded transcripts indicates that one-controller afforded higher levels of interaction, with the use of gestures also increasing the number of interactions seen. Additionally, the result indicated that there were significantly more interactions of the 'shows solidarity', 'gives orientation', and 'gives opinion' categories (defined by the Bales' interaction processes assessment), when using one-controller as opposed to two. Furthermore, there were more interactions for the 'shows solidarity', 'tension release', 'gives orientation' and 'shows tension' categories when using gestures as opposed to the non-use of gestures. Additionally, there were no significant differences in the perceived dominance of individuals, as measured on the social dominance scales, for the amount of interaction displayed, however, there was a significant main effect of group conversational control score on the 'gives orientation' construct, with a higher number of interactions for low, mixed and high scores of this type when dyads had one-controller as opposed to two-controllers. There was also a significant interaction effect of group conversational control score on the 'shows solidarity' construct with a higher number of interactions for all scores of this type when dyads had one-controller as opposed to two-controllers.
The results also indicate that for the WiiConcept there was no difference between number of controllers in the detail in the maps, and that all users found the tool to be useful for the collaborative creation of concept maps. At the same time, engaging in disagreement was related to the amount of nodes created with disagreement leading to more nodes being created.
Conclusions: Use of one-controller afforded higher levels of interaction, with gestures also increasing the number of interactions seen. If a particular type of interaction is associated with more nodes, there might also be some argument for only using one-controller with gestures enabled to promote cognitive conflict within groups. All participants responded that the tool was relatively easy to use and engaging, which suggests that this tool could be integrated into collaborative concept mapping activities, allowing for greater collaborative knowledge building and sharing of knowledge, due to the increased levels of interaction for one-controller. As research has shown concept mapping can be useful for promoting the understanding of complex ideas, therefore the adoption of the WiiConcept tool as part of a small group learning activity may lead to deeper levels of understanding. Additionally, the use of gestures suggests that this mode of input does not affect the amount of words, nodes, and edges created in a concept map. Further research, over a longer period of time, may see improvement with this form of interaction, with increased mastery of gestural movement leading to greater detail of conceptual mapping.

Declaration

The work in this thesis is based on research carried out at the Technology Enhanced Learning Group, the Department of Engineering and Computing Sciences. No part of the material provided has previously been submitted by the author for a higher degree in the University of Durham or any other University. All the work presented here is the sole work of the author and no one else.

This research has been documented, in part, within the following publications:

Foster, C. Burd, L. and Hatch, A.' Exploring concepts collaboratively: Considering how Wii interact,' in ACM *Proceedings of the working conference on Advanced visual interfaces,* AVI 2010, Rome, Italy, May 25-29, 2010.

Foster, C. Tr-tel-08-01: Learning for understanding: Engaging and Interactive Knowledge Visualisation. Technical Reports, Durham University, 2008. URL http://www.dur.ac.uk/ecs/computing.science/research/tel/tecreports/.

.

Acknowledgements

This work is dedicated to my parents Gavin and Lorna Foster who have inspired me in all things that I have done and am yet to do. Without their encouragement and support I would not have got through the many and sometimes lonely hours that have gone into this work. At the same time I would like to dedicate this thesis to my Nan, Eileen, who passed away this year on the 25th February 2010 and my Grandad Ross for being so strong in his loss. I know that she would have been very proud, and it is a shame that she did not get to see its completion. I would also like to dedicate the thesis to my Gran Gladys.

Whilst my family have been there to support me a different family have also helped me to complete this thesis. This thesis would also not have been completed without the help and guidance of Professor Liz Burd, Dr Andrew Hatch and Dr Emma Mercier. I would especially like to thank Professor Liz Burd for introducing to me the interesting research area of Technology Enhanced Learning. I must also thank her for patiently reading my thesis even under the constant weight of paper which threatened to engulf her! Without Liz's support this thesis would not exist and who knows what I would be doing now!

I would also like to thank Andy for his patience in my lack of confidence in my programming capabilities. I remember the drawing of class diagrams on your whiteboard fondly.

SPSS, statistics, these words were all but incomprehensible before Emma helped me to understand them and steady me on my long journey to being able to answer questions with numbers.

Finally, I would like to thank Anna who has shared my life for this past year and made it all worthwhile.

Contents

Figures

Tables

1 Introduction

Interactive screen technologies have become familiar in the classroom and other contexts, while gaming interfaces like the Nintendo Wii provide options for creating gesture-based input commands beyond the move-click capability of a mouse [Milne, 2007] offering new ways of interacting with technology. Bringing these two technologies together provides a new way of creating concept maps; collaboratively building knowledge and understanding of a topic. The potential of new technologies to enable groups of people to simultaneously interact and manipulate a shared display is increasingly coming to the fore, whether through the use of tabletops, e.g. Fleck et al. [2009], augmented tabletops, e.g. Do-Lenh et al. [2009] or via the WiiRemote e.g. Lee et al. [2008]. At the same time recent innovations in asynchronous concept mapping by the Institute for Human Machine Cognition (IHMC), [2010] for example raise new questions about how users of such software can and do interact with each other when carrying out concept mapping tasks in the context of interacting in these new ways.

Concept map interaction is no longer limited to the use of keyboard and mouse, with new undertakings in research designed to explore new interfaces for interacting with concept maps i.e. Do-Lenh et al. [2009], and Baraldi et al. [2008]. However, while these new technologies have been created and, in some cases, applied to the area of concept mapping, there has been little investigation or understanding of how users collaborate around table-tops or large-screens for particular tasks, i.e. concept mapping, beyond the direct application of the new technology to the environment. For example, Baraldi et al. [2008] create concept mapping software for use with a table-top display however they do not investigate the use of multi-modal gesture vs. non gesture interaction when collaborating in small groups when concept mapping. However, there have been several studies which address the impact of tabletop usage on group process and performance in general. For example, Ryall et al. [2004] have reported on the effects of group size and table size on task performance, with Rogers et al. [2009] showing that small groups were more comfortable working around an interactive tabletop than in front of a PC or a vertical display. As a result, group process and dynamics may be dependent, to a large extent, on the availability of input and the interaction modes associated with large-screen technology e.g. Birnholtz et al. [2007] and table-top displays e.g. Rogers et al. [2009].

With regards to configuration of input, Birnholtz et al. [2007] have shown that groups using multiple-mice carried out more parallel work but ended up with a lower perceived quality of discussion than a single-mouse condition. At the same time, Marshall et al. [2008] have shown that the number of input devices alone does not affect the equity of physical and verbal participation of group members. Furthermore, Do-Lenh et al. [2009] found an interaction effect of condition and group heterogeneity on learning outcomes, with qualitative findings, which show how group interactions and strategies differ in two conditions (the table top condition, in which the participants manipulated concepts printed on small pieces of paper and the computer condition, in which participants built a concept map using a traditional computer with a single mouse and keyboard).

Whilst Do-Lenh et al. [2009] offer the first investigation of the use of concept maps in the context of group process and social dynamics, with augmented tabletop displays, what is not clear is how to best interact with large screens for activities that involve the construction of conceptual knowledge when using multiple modes and configurations of input. This is also true of the effect of group process and social dynamics when interacting in this context beyond the initial explorations of Birnholtz et al. [2007] (with mice and keyboard). What little is known about large screen usage and multiple devices has been documented by Birnholtz et al. [2007], with more recent studies such as Fleck et al. [2009] stressing that an alternative approach is needed to consider how aspects of the process of working in small groups can be used to ascertain if enhanced collaboration has occurred: for example, through the equity of participation, and the amount of and type of discussion occurring as well as the amount and type of interaction (as presented here) that occurs when interacting in new ways. This is in opposition to pre- and post-test scores that have been reported as evidence that effective collaboration has occurred using the particular technology e.g. Cappelletti et al. [2004].

At the same time, it has been identified that mode, as well as configuration of input, is important when considering process and social dynamics when interacting in small groups and the subsequent use of interactive technologies in particular contexts. For example, Ha et al. [2008] have investigated the effects of different input devices on users' behaviours and concluded that direct input methods (stylus, touch) support a greater awareness of intention and action than indirect methods (mouse). This is further shown by Hornecker et al. [2008] comparing groups of three people using three mice in contrast to using a multi-touch table through which the affordances of touch input and body movements resulted in increased awareness about other group members.

However, to date, there has been a lack of exploration concerning the effects of the combination of multiple modes of input and configuration of input on group dynamics and social dominance beyond an initial exploratory investigation of Birnholtz et al. [2007] who examined configuration and mode of input (mice vs. laser pointer) with a large vertical display. This is despite recent attempts by Do-Lenh et al. [2009] to understand the effects of tabletop interaction on an expressive collaborative learning task. As a result there have been no systematic attempts to draw together mode and configuration of input, when using multiple forms of, and configurations of input when collaborating in small groups in the context of large screen displays when concept mapping.

The focus of the investigation presented here, therefore, focuses on how configuration and mode of input, affect group processes and dynamics when interacting in specific contexts, beyond the use of mice and keyboards undertaken in early studies e.g. Vogt et al. [2004] and Birnholtz et al. [2007] and their subsequent application to specific tasks such as concept mapping e.g. Do-Lenh et al. [2009]. New technologies that allow students to develop skills in interacting and sharing ideas, are only recently being investigated e.g.

Do-Lenh et al. [2009] with regards to concept maps, for general tangible devices e.g. Manches et al. [2009], and tabletop displays e.g. Marshall et al. [2008], and Nacenta [2007], and large-displays e.g. Rogers et al. [2009] and Tan et al. [2008].

However, the benefits of collaboratively creating concept maps have already been well documented, for both co-located, synchronous and asynchronous, distant groups [see the comprehensive review by Cañas et al, 2003]. These studies show that collaboratively developing concept maps is particularly helpful for understanding complex and ill-structured information e.g. Jonassen et al. [1993]. However these investigations of concept map software usage do not take into account any advances in relation to the forms of interaction and their subsequent application to concept mapping software. Whilst concept maps themselves and their benefit are well established their understanding, in the context of new forms of interaction, is not. As with other studies of collaborative learning [e.g. Mercier, Goldman & Booker, 2009] most research on collaborative construction of concept maps finds that the quality of the interactions between participants has a huge impact on the outcomes for the group. Results from these studies found that more complex interactions and elaborate discussions led to better concept maps. Yet these investigations now find themselves disassociated from any understanding of the impact of mode and configuration of input on group processes when used collaboratively in specific contexts e.g. concept mapping beyond the interaction of mouse and keyboard last investigated by Birnholtz et al. [2007]. New technologies exist, but their application to concept mapping and impact upon group dynamics in this context needs to be investigated in the context of new forms of interaction which did not previously exist at the inception of concept mapping.

Having identified the focus of this investigation it is important to also clarify what this thesis will not do. This thesis, while situated in a Higher Educational environment, will not attempt to evaluate the educational outcomes or associative learning outcomes that occur in conjunction with, or as a result of, the interaction processes applied to concept mapping when manipulating configuration and mode of input in the context of the application of new forms of interactive technology with concept mapping. It is clear that to evaluate educational outcomes is complex and is still open to debate e.g. Do-Lenh et al. [2009] (and, well beyond the remit of any undertaking of the analysis of mode and configuration of input outlined as the focus of this thesis). However, this thesis will consider group process i.e. the impact of the interfaces on the concept maps that participants created during the tasks, but not any subsequent learning outcomes or benefit attributed to this process and resulted in the formulation of research question six as defined in section 1.1 of this chapter. Such an undertaking is in line with the research carried out by Birnholtz et al [2007] when investigating multiple input devices with large screens. Future research would then consider the impact of these devices on learning-outcomes when collaborating with these new forms of technology.

In this thesis, the software created (WiiConcept) is presented which allows for the multiple use of WiiRemote controllers, with and without the use of gestures, and their subsequent use with large displays for a concept mapping task, creating a tool by which concept maps can be collaboratively created on large wall based displays. At the same time, an investigation is presented into the use of this system when collaboratively concept mapping in this way.

To study the influence of mode of input and configuration on group interaction and the effect on concept map outcomes, this research was conducted using a single between-groups factor of input configuration of two levels (one-controller and two-controllers) and a single within-groups factor of interaction style, consisting of two levels (controller(s) without gestures and controller(s) with gestures enabled). The factor of interaction style was fully counterbalanced with each set of pairs completing only one concept map using the controller configuration (without and with gestures enabled). Indeed, to ensure that there were no confounding variables i.e. between that of input configuration and mode of input, input configuration is the only variable changed between groups and interaction style the only variable changed within groups.

Pre - and post-test measures were collected via questionnaires based on the existing work of Birnholtz et al. [2007] and Smith [2009]. Further data on perceived interaction behaviours, as well as video of interactions during two thirty minutes experimental conditions were also collected and analysed via Bales' Interaction Process Analysis [1950]. Semi-structured interviews were also carried out to provide further qualitative results and explanation for the quantitative results obtained from the videos and questionnaires. This data was then used to answer the research questions and hypothesis outlined in section 1.1. below and which constitute the results outlined in Chapter 6 of this thesis.

1.1 Research questions and hypotheses

This thesis addresses six main research questions. These questions and their major hypotheses are now summarised here and discussed in depth in Chapter 7 of this thesis.

Section 1 of this thesis has introduced the range and focus of the research explored in subsequent chapters of this thesis. The research questions introduced here focus on the principle aim of investigating mode of input and configuration of input on small group dynamics and processes when concept mapping in a higher educational environment. As a result the research questions can be categorised as addressing these criteria (that of mode and configuration of input).

As proposed by Rogers et al. [2009], group process and associative performance may depend to a large extent on the availability of entry points and in terms of interaction modes. In terms of group process, it has been shown that multiple mice solutions are preferred by children over a single mouse, Stewart et al. [1999], encouraging discussion, Kerawalla et al. [2008], positively impacting their engagement with the task, such as more on-screen gestures, with the result of less off task behaviour, subsequently leading to more enjoyment of the activity Scott et al. [2003]. However, Marshall et al.

[2008] show that the number of input devices by themselves effects neither the equity of physical and verbal participation of group members, nor the amount and type of interactions that they display.

As a result, it is likely, that the mode of input is also an important factor e.g. Do-Lenh et al. [2009]. Ha et al. [2006] have also investigated the effects of the different input devices on users' behaviours and concluded that direct input methods (stylus, touch) support a greater awareness of intention and action than indirect methods i.e. mouse. To date, there has been a lack of investigation/evidence concerning the impact of mode and configuration of input on small group dynamics when concept mapping, with no consideration of how tangible devices and their configuration of input impact upon small group dynamics beyond recent initial investigations by Do-Lenh et al. [2009]. Furthermore, there is no consideration as to the impact such devices and their configuration may have in terms of group dynamics, and how their use and configuration may impact upon interaction style and the type of interaction shown, with initial experiments in this area considered in the context of mouse based input e.g. Birnholtz et al. [2007]. As such, the research questions shown here focus on these major objectives and are as follows:

RQ1. Does number of controllers, with and without use of gestures, influence the amount of interaction in a group when constructing concept maps?

H1a: It was hypothesised that:

- Groups would exhibit higher amounts of interaction when using one-controller as opposed to two.

H1b: It was also hypothesised that:

- Groups would exhibit higher amounts of interaction when using the software with gestures rather than without gestures.

RQ2. Does number of controllers and with and without use of gestures influence the type of interaction seen in groups?

H2: It was hypothesised that:

- Groups in the single controller condition would experience more discussion of group process. As such, there would be higher amounts of interaction for task neutral areas (as determined by Bales' IPA [1950] e.g. gives opinion and orientation), than the two-controller condition where groups would act in their own best interest in the multi -controller condition. Because it is expected that more interaction will occur when using gestures as opposed to non-gestures, groups in the single controller condition with gestures will elicit the highest scores in these areas.

- Consequently, with single controller groups more likely to discuss group process, it is expected that they will show higher levels of solidarity and lower levels of tension when using one-controller as opposed to two-controllers. In the two-controller condition it will be expected that there will be less group discussion in relation to opinion and orientation and therefore there will be increased levels of tension and antagonism.

- Higher levels of tension and antagonism will occur when using gestures as opposed to without gestures for both one and two controllers. The use of gestures will see increased levels of socio-emotional area negative categories of interactions (as determined by Bales' IPA [1950]), as groups struggle to use gestures. However, whereas negotiation is likely to occur when using one-controller as to who may be 'best' at gesturing, it is likely that with a controller each more socio-negative interactions may occur as one user may be 'better' at gesturing than another. Therefore, interactions of these types will be highest for two-controllers with gestures as there will be less group process discussion, and, as a consequence, less group solidarity will be displayed, and therefore, more group antagonism, disagreement and tension expressed in interaction in these categories.

RQ3. How does the level of social dominance, controller and gesture configuration influence the amount of interaction in a group?

H3: It was hypothesised that:

- High levels of social dominance i.e. with regards to conversational control would lead to increased levels of interaction for one-controller usage as opposed to two, with more opportunity for this control to occur for one-controller usage i.e. possession or non-possession of the controller. At the same time, increased levels of interaction would be reported for non-use of gestures as opposed to gesture usage with the unfamiliarity with gestures reducing the overall amount of interaction seen, and therefore acting as a levelling device with regards to the amount of interaction seen.

RQ4. How does the level of social dominance influence the type of interaction in a group?

H4: It was hypothesised that:

- Varying degrees of social dominance may lead to particular types of interaction. For example, high levels of social dominance may force people to interact with each other in different ways, as one or both participants fight for the use of a controller or perhaps control of the conversation. As such, it may be possible that groups of both high scoring participants on the social dominance scale may show increased levels of the 'shows tension' category when using one-controller, as opposed to two, as they fight for control of the conversation. However, these levels may be reduced for mixed dominance groups, with conversational control interchanging between roles of observer and controller, and fewer for low conversational groups. It is also possible that when using a single shared mouse, mouse possession may serve as a proxy for conversational control e.g. [Birnholtz et al. 2007]. As a result, groups showing varying degrees of conversation control scores may express different types or greater numbers of interaction categories. While certain people may tend to be higher or lower on the social dominance scales than others, it has been shown that certain communication technologies can impact upon this e.g. [Huang, 2002]. As a result the level of social dominance, it is expected, will influence the type of interaction seen within groups, with varying levels of social dominance leading to different types of group interaction displayed.

Q5. Does level of social dominance influence who uses the controller first?

H5: It was hypothesised that:

- With an initial assertion established through the control of the controller it is possible that the overall perceived social dominance of that user might be affected. It might also be expected that more exchanges of controller would occur in the 'with gesture' condition as opposed to the 'without gesture' condition as the participants may not be as confident at gesturing as opposed to pointing and clicking and, therefore, when they perceived themselves to have 'failed' at gesturing they would pass the controller to their partner.

Q6. What is the relationship between amount and type of interaction and process outcomes (e.g. number of nodes created)? The process outcomes in this instance being the concept maps created as part of the process of interaction and completion of the tasks carried out.

H6: It was hypothesised that:

- Groups would create more nodes, (and subsequently words and edges) in the one-controller condition than the two-controller condition, with gesture usage eliciting more nodes, words and edges than without gesture usage.

1.2 Objectives and criteria for success

This research aims to investigate the impact mode and configuration of input has on the construction of concept maps, amount of interaction and interaction styles, levels of social dominance and attitudes to concept mapping when using a large display.

The success of the research will be judged against the following:

A. To better understand the role of gesture vs. non-gesture and use of multiple controllers with regards to the amount and type of group interaction and apply Bales' Interaction Process Analysis in this context.

B. To determine what relation levels of interaction have on the construction of conceptual knowledge i.e. are more nodes constructed in concept maps when constructed in this context?

C. To encourage and motivate students to consider their conceptual understanding of computer science modules, through innovative interaction techniques.

D. Understand whether having initial control of the controller influences social dominance in this context.

E. To develop a proof of concept prototype tool to demonstrate the use of multiple WiiRemote controllers with and without gestures.

An evaluation of this research against these criteria is provided in Chapter 7 of this thesis.

1.3 Thesis overview

The outline of the remainder of this thesis is as follows:

Chapter 2 distinctly addresses related educational theory relating to concept mapping. This discussion is framed within the context of Higher Educational learning, looking at the problems and issues facing learning, in this context, and revisits concept mapping as a means of solving these educationally orientated issues.

Chapter 3 introduces new directions taken in relation to Human Computer Interaction and identifies new modes of interaction and discusses the problems and related issues within this literature. This consideration then focuses on concept mapping software and how these new interaction techniques can be used to encourage students to interact when using conceptual mapping software.

Chapter 4 discusses the software design and subsequent implementation of the WiiConcept software. This chapter moves on to discuss the requirements of the software, the concept mapping software to be re-used as part of the development process, the incorporation of the multiple controllers and the technical challenges faced. This chapter then considers the WiiConcept software approach including the design of the system structure and components as well as the design of the user controls as means through which to interact with the system.

Chapter 5 describes the experimental design and experimental method undertaken following the creation of the WiiConcept software as outlined in chapter 4. This discussion also includes the measurements used to test the hypotheses under study as well as the subsequent data analysis.

Chapter 6 reports the results and analysis of the research in relation to the research questions posed and their hypotheses proposed in this chapter.

Chapter 7 summarises the results before evaluating them in the context of the related literature. Such an evaluation then considers an informal discussion of the issues and merits of the research as well as the software. This leads into the conclusions of the thesis and further summarises the research in the context of its contribution and limitations. The criteria for success, as identified in Chapter 1, are compared to the results of this thesis and as a result future research areas of research are suggested.

2 Literature review

2.1 Introduction to the literature review

The aim of this initial chapter (chapter 2) is to provide an introduction to user centered approaches to learning, as well as the movement towards deep, rather than surface learning approaches in Higher Education. The focus of the discussion in this chapter then considers concept mapping (as a form of a deep approach to learning) and the problems and benefits associated with its use.

Having first situated this initial discussion in a Higher Educational and specifically concept map driven context (and not a learning driven context) the subsequent chapter (chapter 3) discusses recent technological advances in interaction. As such, this chapter considers technological advancements in input design and further examines how these new forms of interaction offer new opportunities for understanding small group interaction, (particularly in the context of concept mapping as described here in chapter 2).

As these topics are introduced, the discussion focuses on the core fundamentals of the thesis, being the use of interactive technology with concept mapping and the subsequent impact on group dynamics experienced via the variation of mode and configuration of input when interacting in this way. The core focus of this thesis therefore is concerned with the impact of mode of input and configuration of input on small groups' interactions in the context of concept map-based collaborative tasks in higher education, as initially introduced in chapter 1 and further discussed throughout this literature review and subsequent chapters.

What is clear is that the benefits of collaboratively creating concept maps have been well documented for both co-located and synchronous and asynchronous distant groups e.g. Cañas et al. [2003]. These studies show that collaboratively developing concept maps is particularly helpful when students are trying to understand complex and ill-structured information e.g. [Holley and Dansereau, 1984; and Jonassen et al. 1993]. However, their use is still infrequent in Higher Education in the UK with motivation to use them being low, e.g. Farrand et al. [2002] and they are not always received positively by students or teachers e.g. Santhanam et al, [1998]. What is not clear, (with the advent of new forms of interaction), is what impact, if any, specific forms of interaction, (in specific contexts such as concept mapping), have on small groups' interaction when considering mode and configuration of input on small groups dynamics, since Birnholtz et al. [2007].

Again, what is clear is that today, concept map usage is no longer limited and should not be limited to the use of keyboard and mouse, with new undertakings in research designed to explore new interfaces for interacting with concept maps i.e. Do-Lenh et al. [2009], and Baraldi et al. [2008]. Therefore, it is increasingly important to understand how these new technologies in this and other contexts, can be incorporated into existing pedagogical activities, (the focus of this investigation being concept maps) and as a consequence of their use discover how varying degrees of input and configuration impact upon small group interaction as initially investigated by Birnholtz et al. [2007] in the context of mouse and keyboard interaction, but in the context of these new technologies.

As a result of these observations the following literature review is structured under the two major themes of this thesis. These themes are:

1. The Higher Educational research context i.e. concept mapping, its use and the theory behind it, followed by a discussion of;
2. group dynamics and small group interaction and new forms of interaction and their potential application to this context.

2.2 Related educational theories – an introduction

The educational approaches outlined here are to be considered as providing the context through which the latter consideration of mode and configuration of input is based, as a means of better understanding interaction when applied to concept mapping in this context. The context is not the focus of the investigation, rather the situation in which it is necessary to understand how mode and configuration of input impact upon group dynamics when interacting in this context. The approaches to learning therefore introduce the context which justifies the use of new technologies in these contexts, but any resultant learning derived from these new technologies is not the focus of this thesis. Rather, having in the first instance established the context with regards to educational theory related to concept mapping, the subsequent application of this theory in the form of concept mapping (and the associative benefits and problems its use in an educational context bring) will form the second part of this chapter. The discussion in chapter three, will then consider how technology when applied in various modes and configurations may provide new ways through which to interact in small groups when collaborating in these contexts outlined in this chapter. The subsequent investigation of these new technologies will then go on to consider how group dynamics are affected when used and the associative effects these forms of interaction have on amount and type of interaction when collaborating in these new ways.

In order to gain a better understanding of the use of concept mapping and its subsequent use with traditional and new forms of interaction a general overview of some of the relevant educational theories is now presented. This section will outline the main theories that are particularly applicable to the use of concept mapping. The educational material presented is intended as context, not as a basis through which to evaluate the research undertaken against as the focus of this thesis (as outlined in chapter 1) does not investigate/or evaluate the educational outcomes or benefits.

2.2.1 Constructivism

It is not feasible to analyse and discuss the entirety of constructivism, the material of which would comfortably constitute a book or perhaps even a series. Rather, the aim of this section is to introduce the reasoning behind these ideas, and the construction of meaningful learning, discussed in subsequent sections of this thesis, can be considered in light of the background discussed here.

Formalisation of the theory of constructivism is generally attributed to Jean Piaget [1947]. Piaget's central concern focused on the processes through which humans construct their knowledge of the world. Piaget articulated mechanisms through which knowledge is internalised by learners through their actions on objects in the world. Such mechanisms evolve as a process of adaptation to more complex experiences. As a result, new schemes come into being by modifying old ones. The result is that intellectual development can be seen as a progressive adaptation of the individual's cognitive schemes to the physical environment i.e. Driver et al. [1994]. As such, teaching approaches in science, for example, based on this perspective focus on providing children with physical experiences that induce cognitive conflict and hence encourage learners to develop new knowledge schemes that are better adapted to experience. Therefore, students associated with this perspective are encouraged to be actively engaged in attempting to understand for themselves.

The process of learning can therefore be seen as involving a process of conceptual change with studies showing that students do not come into science instruction without any pre-instructional knowledge or beliefs about the phenomena and concepts to be taught e.g. Duit and Treagust [2003]. Rather, students already hold deeply rooted conceptions and ideas that are not in harmony with generally accepted views of science or are even in stark contrast to them [see, Duit and Treagust, 2003 and Novak, 2002].

Learners can therefore be considered as constructing meaning from the old information and models that they have and the new information they acquire, and they do so by linking the new information to that which they already know. For Piaget [1947], it is through the processes of ‘Assimilation’ and ‘Accommodation’ that learners are able to construct new knowledge through their experiences with objects in the world. This process of Assimilation occurs when individuals' experiences are aligned with what can be considered their internal representation of the world. The process of Accommodation re-imagines the learner's mental model of the external world to fit new experiences, often through, though not limited to, interaction with new objects. One technique that is known to help students build useful mental models is concept mapping.

Constructivism as a theory has many forms which include radical, Roth, [1999], cognitive, Doolittle [1999] and social Roth, [1999] variations. However, despite any differences in perspective all constructivists share the same view that learners construct new knowledge and meaning from their experiences. The intricacy of how each different constructivist perspective accounts for this is not relevant to the discussion within this thesis and has, as a result been omitted.

2.2.2 Meaningful learning

Having briefly outlined constructivism the concept of meaningful learning is now introduced, as a precursor to the exploration of conceptual understanding, which will subsequently lead onto a consideration of the resultant methodologies and tools through which to facilitate meaningful learning (including concept mapping).

Ausubel [1968] describes the process of accumulating meaningful learning as involving the acquisition of new meanings. That is, the emergence of new meanings in the learner that reflects the completion of a meaningful learning process. It is in this learning process that the conditions of meaningful learning exist, whereby symbolically expressed ideas are related in a non-arbitrary and substantitative (nonverbatim) fashion to what the learner already knows, namely, to some existing relevant aspect of his structure of knowledge (for example, an image, an already meaningful symbol, a concept, or a proposition). As a result, irrespective of how much potential meaning there may be in a particular proposition, if the learner's intention is to memorise it arbitrarily and verbatim both the learning process and the learning outcome must be rote or meaningless [Ausubel, 1968]. If neither the process nor the outcome can possibly be meaningful then the learning task itself is not meaningful no matter how motivated the learner is to learn. Ausubel has therefore made the clear distinction between rote learning, where new knowledge is arbitrarily incorporated into cognitive structure, and meaningful learning where the learner makes a conscientious decision to incorporate new knowledge into existing knowledge structures.

The relationship between students' epistemologies and their approaches to learning science, and the subsequent influence this has on their choices of learning strategies and whether or not they integrate what they have learnt is well documented [see Edmondson and Novak 1993, Roth and Roychoudhury 1993, 1994, and Lee and Brophy 1996]. Indeed, the concept of motivation to learn is related to students' goals and learning strategies during task engagement, which subsequently influences the quality of their cognitive engagement, which in turn influences the quality of their cognitive engagement in the activity [see, Lee and Brophy, 1996]. Students are therefore likely to employ deep cognitive and self-regulated strategies (if they are motivated in the first instance) such as integrating information and monitoring comprehension which result in meaningful learning or conceptual understanding e.g. Chin and Brown [2000]. Therefore, in Ausubel's Assimilation Learning Theory, variation in amount of recall depends primarily on the degree of meaningfulness associated with the learning process. Information learned by rote, cannot be anchored to major elements in cognitive structure and hence form a minimum linkage with it. Unless materials learned by rote are restudied repeatedly to achieve over learning (continued study after error-free recall has been achieved), they cannot be recalled several hours or several days after learning [Novak, 1998].

In summary, meaningful learning as posited by Novak [1998] has three fundamental requirements:

- Relevant prior knowledge: That is the learner must know some information that relates to the new information to be learned in some nontrivial way.

- Meaningful material: That is, the knowledge to be learned must be relevant to other knowledge and must contain significant concepts and propositions.

- The learner must choose to learn meaningfully: That is, the learner must consciously and deliberately choose to relate new knowledge to knowledge the learner already knows in some nontrivial way.

2.2.3 Deep and surface learning approaches

Crucial to the understanding of meaningful learning described in section 2.2.2 are the deep and surface based approaches undertaken by students' when carrying out activities designed to promote learning.

The constructs of deep and surface learning were first introduced by Marton and Saljo [1976]. The surface approach to learning arises from an intention to get the task out of the way with minimal effort whilst appearing to meet the requirements of the task. This approach results in low-cognitive-level activities as opposed to higher-level activities that are often required to do the task properly i.e. what can usually be considered as a deeper approach to learning. As a result, deep learners therefore attempt to delve deeper and understand the relationships between concepts, and attempt to incorporate this new knowledge with prior learning. Often therefore, they adopt a critical and reflective attitude to information e.g. Boyle et al. [2003]. What is of critical importance however is the distinction between the two approaches (that of deep and surface learning) which lies in the deliberate intention or absence of intention to understand e.g. Kember [1996].

Critically, the ability to reformulate information through understanding (as espoused by deep approaches to learning) in varying contexts can be considered ‘a more useful skill' (especially in terms of new corporate expectations), as opposed to the regurgitation of information without understanding and low levels of information transferability. Without this, the result is ‘fractionation’ [Barr and Tagg, 1995] having to learn disconnected concepts and sub-skills without an understanding of the larger context into which they fit and which gives them meaning. As a result, approaches and tools which address these concerns may be beneficial.

Beyond deep and surface approaches, learners can also adopt a third approach to learning, that of ‘strategic learning’ [Entwistle and Waterston, 1988]. This strategic approach allows learners to adapt their approach to learning to ensure the best possible grades [Diseth and Martinsen, 2003]. As a result, a learner is not aligned to any particular modality or strategy, other than the strategy or collection of strategies that engender success. Therefore, learning can be considered as strategic [Warburton, 2003]. Of course this does not mean to suggest that students, cannot, of course, take responsibility for their own learning. Science students can be encouraged to use deep learning approaches when prompted to ask questions, make predictions and develop explanations, more readily in a cooperative, active learning environment than with a traditional lecture format [Warburton, 2003].

2.2.4. Co-operation vs. collaboration

For many researchers, the terms collaborative and cooperative have similar meanings, and there is, as a consequence, considerable debate as to whether they are broadly the same. Some authors use the terms cooperative and collaborative interchangeably to mean students working interdependently on a common learning task [Smith et al. 2005]. Their primary difference is that cooperative learning requires carefully structured individual accountability, while collaborative does not. This is despite numerous authors such as Barkley, Cross and Major [2004], who use the term collaborative learning to refer to predominantly cooperative learning research and practice [see Smith et al. 2005].

Panitz [1996] provides an authoritative review of the perceived differences between cooperative and collaborative group work in which he cites the work of Myers [1991] and Rockwood [1995] who point out some of the key differences between the two concepts.

The ‘flow it around model' [Smith et al. 2005] emphasises that teaching and learning is predicated on working together to accomplish shared goals. It is within this cooperative model and through associative cooperative activities that individuals seek outcomes that are beneficial to themselves and beneficial to all other group members. Therefore and central to the idea of cooperative learning, is the instructional use of small groups, so that students work together to maximise their own and each other’s learning e.g. Johnson et al. [1991]. However, it is important to remember that there are a number of different approaches to cooperative learning that have been proposed by different individuals. The most widely cited are those of Johnson et al. [1994], and Slavin [1991], and the reader should consult these texts for a broader discussion of approaches to cooperative learning, which are unfortunately too broad a topic to cover within this thesis.

Crucially, if cooperative learning can be defined in terms of students and teachers working together in what can be considered an unequal partnership, then collaborative learning on the other hand can be considered to be the production of knowledge by consensus amongst peers irrespective of whether or not a teacher is involved. Thus, and in conjunction with Brufee [1993] it is not up to the teacher to monitor group learning, but rather the teacher's responsibility is to become a member, along with students, of a community in search of knowledge. Therefore, subsequent collaborative learning activities vary widely, but most centre on students' exploration or application of the course material, not simply the teacher's presentation or explanation of it.

2.2.5 Problems with cooperative and collaborative learning

Learning from and with peers in small groups is a complex task and often difficult to achieve effectively. Crucially, if executed poorly, and in a non conversant manner, it can actually stigmatise low achievers, rather than encourage them, and create dysfunctional interactions among students. Thus the process of creating successful group work is not simply a matter of putting students together. Students do not automatically become more involved, thoughtful, tolerant, or responsible when working with others e.g. Blumenfeld et al. [1996]. Accordingly, the effects of group work depend on how the group is organised, what the tasks are, who participates, and how the group is held accountable [Blumenfeld et al. 1996].

Therefore, for group work to succeed, teachers and lecturers must consider norms, tasks, and the constituency of the group and the level of help that is required and sought by the group individually and as a whole. Additionally, teachers must also, according to Johnson and Johnson [1998] understand the nature of cooperation and the essential components of a well-structured cooperative lesson in order to effectively use cooperative learning. However, a study by Sparapani et al. [1997] shows that teachers' interpretation and application of cooperative learning is not always consistent with what the academic research recommends. As a result successful group work requires students to share ideas between one another, to listen to each other and to reconcile points of view, which can often be conflicting.

Unfortunately, such norms do not necessarily suffuse classrooms today. In addition to this however, cooperative and collaborative learning requires interpersonal and small-group skills, yet students invariably do not have the skills necessary through which to interact successfully. The pupils therefore must often be taught these skills for high quality collaboration to occur. Such a scenario is required as many students are not used to working in groups and are often used to working individually, receiving individual rewards for producing the right answers in competition with their fellow students for the highest grades.

Crucially, a major problem can be considered the failure of some group members to contribute. Some group members may seek to gain a 'free ride' or participate in 'social loafing'. Obviously, if a group is assessed with the same grade, and all group members do not work equally then the group dynamic has failed and could have an effect on individual's attitudes and experiences with working in groups in the future. Furthermore, forceful students may also dominate discussions, pressure others to accept their perspective, or force conclusion on the group e.g. Blumenfeld et al. [1996]. Rejected members may withdraw from the group process.

A further problem that has been identified surrounds the concept of group composition, whereby the mix of achievement levels, race and ethnicity and gender influences how students interact, who benefits, and whether students actually engage in serious thought [see, Blumenfeld et al. 1996]. Cohen and Lotan [1997] contest that status differences for example become more prominent, where minority students are generally presumed to be less competent by majority students and can therefore be rejected or excluded from the learning situation. In many ways, therefore, what happens in the classroom and within the group dynamic is vital to ensuring that group work is effective and productive in facilitating learning.

Additionally, many factors affect a student's motivation to learn [Bligh, 1971] such as interest in the subject matter, perception of its usefulness, general desire to achieve, self-confidence and self-esteem, as well as patience and persistence. At the same time, it is also false to assume that not all students are motivated by the same goals [Davis, 1993]. As a result, students who are not actively involved in group work could be involved in off-task activities or passively observing others at work.

2.3 Research context: Concept maps: A knowledge visualisation tool for collaboration

2.3.1 Knowledge visualisation

For cognitive psychologists the essence of knowledge is structure. Therefore, if the knowledge within a content domain is organised around central concepts, to be knowledgeable implies a highly integrated conceptual structure among those concepts [see Ruiz-Primo, 2004]. As a result, as expertise in a domain grows, through learning, training, and/or experience, the elements of knowledge become increasingly interconnected. As such, several attempts have been made to represent cognitive structure graphically. For instance, the ‘association memory' of the information processing theorists [Newell, 1977], the ‘entailment structure' of conversation theory [Pask 1976a, b], the ‘frame-system' theory for memory [Minsky, 1977], and the networks of semantics [Rumelhart, 1977] all incorporate a means of representation aimed at understanding and modelling the learning process, and each is set within a theoretical program.

However, concept mapping, as developed by Novak [1979], differs from these in being a practical strategy aimed at increasing students' ability to learn meaningfully, [see Ausubel, Novak and Hanesian, 1978], and at developing their understanding of their own learning approaches and knowledge base [see Novak 1985]. Researchers have therefore taken different representational approaches to capture this organisational property of knowledge e.g. Goldsmith, Johnson and Acton, [1991], Novak and Gowin, [1984], Novak, Gowin, Johansen, [1983] and White and Gunstone, [1992].
The undertaking of making knowledge visible so that it can be better accessed, discussed, or generally manipulated is a long standing objective in knowledge management e.g. Eppler, and Burkhard [2004]. The general field of knowledge visualisation accordingly evaluates this use of the visual through which to improve the creation and transfer of knowledge between at least two people. As a result examples of knowledge visualisation formats are often complex, reasoned and theory-driven conceptual diagrams, concept maps,

interactive visual metaphors (such as an iceberg of organisational culture), or knowledge maps [Eppler and Burkhard, 2004]. It is within this complex environment that a general introduction will be provided to such methods as forms of graphic visualisations; however, the main focus of this discussion will concentrate on concept maps.

2.3.2 The Invention of concept mapping

Concept maps, as defined by Novak and Cañas [2006a], ‘show the specific label (usually a word or two) for one concept in a node or box, with lines showing linking words that create a meaningful statement or proposition' see figure: 2.1.

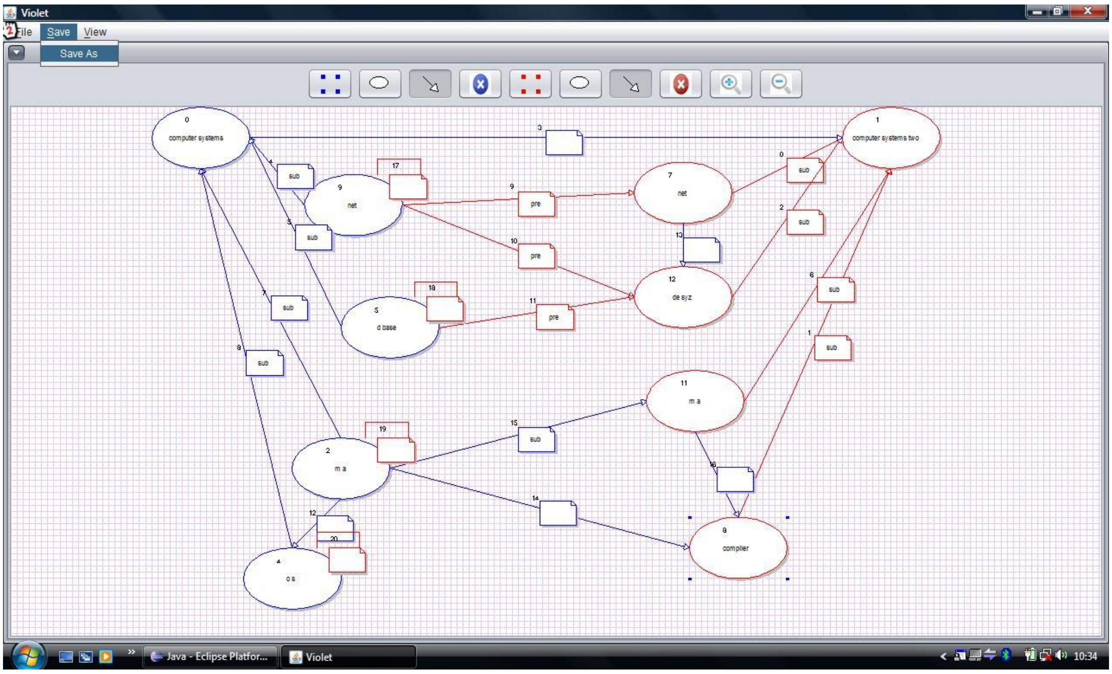


Fig 2.1: Example concept map created in the WiiConcept system.

These concepts are arranged hierarchically with the most general, most inclusive concept at the top, and the most specific, least general concepts towards the bottom. There may also be cross-links showing relationships between concepts in two different areas of the concept map [Novak and Cañas, 2006a]. Accordingly, cross-links help the concept mapper to see how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer [Novak, and Cañas, 2006b]. It is these two features of concept maps that are important in the facilitation of creative thinking: the hierarchical structure that is represented in a good map and the ability to search for and characterise new cross-links.

Concept maps differ from other types of mapping systems, such as Knowledge Maps, Conceptual Graphs, and Mind Maps because of their grounding in Ausubel's Assimilation theory of learning, their semantic and syntactical (structural) organization, the nature of concepts that comprise the nodes in a Concept map, and the unconstrained nature of linking phrases [see Cañas et al. 2003]. Other representational schemes, such as mind maps [Buzan and Buzan, 2006], usually lack one or more of the above characteristics. Other forms of knowledge representations have been described in detail by Sowa [2006].

2.3.3 Application of concept maps in an educational context

Concept maps in educational settings are a very versatile instrument. Concept maps have been used to organise instructional material for individual courses or entire curricula, for creating navigational aids for hypermedia, as a scaffold for understanding, to identify problems in learners' knowledge structures, and to teach critical thinking amongst many others [see comprehensive review by Cañas et al. 2003]. Numerous educational applications of concept mapping can be identified [see comprehensive review by Cañas et al. [2003]; however Jonassen [2000] limits these functions, as a learning tool, to four ways: a study guide, a knowledge integration tool, a planning tool, and a tool for assessing what learners know.

Critically, one of the powerful uses of concept maps is not only as a learning tool but also as an evaluation tool, thus encouraging students to use meaningful-mode learning patterns. Concept maps are also effective in identifying both valid and invalid ideas held by students (this will be discussed in section 3.5.4 of this thesis). However, another important area for the use of concept maps, which is often overlooked, because of its very simplicity, is the notion that concept maps can represent a vast amount of information. For example, Novak and Cañas [2006] found that they could easily transform information in an interview transcript into a concept map. They found that a 15-20 page interview transcript could be converted into a one-page concept map without losing essential concept and propositional meanings.

Cañas et al. [2003] have identified the works of Plotnick [1997] and White and Gunstone [1992] as useful references that have discussed the use of concept maps in education. Cañas et al. [2003] have also identified further overviews of educational applications of concept mapping i.e. Pankratius and Keith, [1987] and Novak and Gowin [1984].

2.4 Uses of concept maps

2.4.1 Identifying current understanding, misconceptions and conceptual changes

Concept maps have been used to examine students' prior knowledge, to track students' progression of knowledge throughout the length of a course, and to compare students' and teachers knowledge basis etc. e.g. Adamczyck and Willson [1996], Darmofal et al. [2002], Kinchin and Hay [2000], and Songer and Mintzes [1994]Concept maps have also been used to identify specific misconceptions in knowledge e.g. Edmondson and Smith [1996] and as a tool for investigating conceptual change e.g. Chi [1994], Duit and Treagust [2003], Novak [2002] and Rebich and Gautier [2005].

2.4.2 Concept maps and collaboration and cooperation

Since the late eighties, researchers have been exploring the potential of collaborative concept mapping (CCM) to support learning. Within this research, students usually construct concept maps in small groups e.g.

Basque and Lavoie [2006], Chiu et al. [1999] and Chung et al. [1999]. However, since the mid-1990s computer supported/mediated uses of concept maps have been researched, with additional investigations carried out into web-based tools which facilitate collaborative functionality e.g. Chiu et al. [1999]. It has been proposed that there are three forms of collaborative concept map creation processes discussed within the literature: face to face computer-mediated CCM, synchronous networked CCM and asynchronous networked CCM e.g. Kim et al. [2005].

The benefits of collaboration in conjunction with concept maps have been well documented in a number of studies, both in terms of face-to-face and at distance learning, either synchronous or asynchronous e.g. Cañas et al. [2003; 2004]. More specifically, Stoyanova and Kommers [2002] have found that a 'shared' mapping mode (synchronous CCM) results in better performance compared to a distributed mode (shared individual Cmaps until a common vision attained) and a 'moderated' mode (shared individual CMap adjusted by a moderator). As a result, they showed that shared cognition, when all members collaboratively construct a concept map, is more effective than moderated and distributed collaboration. Additionally, Chiu [2004] found that performance is lower when roles are rotated than when they are assigned, given, or left open. Additionally, Basque and Pudelko [2004] also found that the performance in a face-to-face condition is better than in an asynchronous one. When a face-to-face condition is contrasted to a synchronous one, no significant difference was found in group achievement [Khamesan and Hammond, 2004, 2005].

When considering the effects of CCM on learning, CCM compared with individual concept mapping or to other forms of collaborative activities has been documented, according to Basque and Lavoie [2006], as being more beneficial for learning e.g. Okebukola and Jegede [1988], Eseiobu and Soyibu [1995] Czerniak and Haney [1998], Stoyanova and Kommers [2002] and Ledger [2003]. However, Basque and Lavoie [2006] also found some no-significant-difference studies e.g. Okebukola, [1992] van Boxtel et al. [2000] and Suthers and Hundhausen [2001].

Finally, the nature of the interaction among participants appears to have an influence on whether or not effects of collaboration are positive [Cañas et al. 2003]. Generally, results show that more interactions and more elaborate, high-level, and complex interactions lead to better performance. Other researchers, most notably Chung et al. [1999], on the other hand, have found that collaboration in conjunction with concept mapping does not appear to benefit students.

Significantly, however it would appear that there were no studies which investigated the use of gesture-based interaction methods through which interaction occurred with concept maps.

2.4.3 Attitudes to concept maps in an educational context

Laight [2006] has investigated student attitudes to pre-prepared concept maps. Student attitudes to pre-prepared concept maps (introduced in Stage 2 MPharm and BSc Pharmacology lectures) were examined in relation to preferred learning styles according to the Felder–Silverman model. There was no statistically significant influence of dichotomous learning style dimension (sensing/intuitive; visual/verbal; active/reflector; sequential/global) on the self-reported utility of such concept maps to learning. However, when strength of preference was analysed within each dimension, moderate/strong verbal learners were found to be significantly less likely to self-report concept maps as useful relative to mild verbal learners.

Taber [1994] provides a less empirical analysis, than that reported by Laight [2006], which also provides a useful insight into student attitudes to concept maps. Taber [1994] considers the first exposure to concept mapping for a class of students enrolled on a one year revision course of A-level Physics. The A-Level students created concept maps, and were then asked to note their reactions, i.e. whether it was fun, difficult and did it make them think? Little data is made available as to the overall view of the class with regards to concept maps, though the responses seem mixed, with 'one student [thinking] the exercise ‘not fun but necessary,' but others disagreed as may be seen from their comments: ‘fun,' 'I quite enjoyed doing it,' ‘I think this is a very pleasant experience', ‘it was interesting' and even ‘very interesting' [Taber, 1994]. Taber [1994] concludes that such comments suggest that, for some students at least, concept mapping is an activity where the learner is able to offer judgments on current learning which can form the basis of planning for future study.

2.4.4 Efficacy of concept maps

The purpose of this section is to introduce studies which provide an insight into the effectiveness of concept mapping as a learning tool. The purpose is not to describe these studies, as comprehensive reviews have already been undertaken by Cañas et al. [2003] and Horton et al. [1993]. After introducing the major studies pertaining to the identification of the effectiveness of concept maps, the discussion will focus on an introduction to some of the benefits and problems associated with concept maps. Furthermore, as Cañas et al. [2003] have noted, the issue is not whether or not concept mapping enhances learning. Like any other tool, the effectiveness of concept mapping depends on how it is used and the conditions in which it is used.

Cañas et al. [2003] also provide an excellent overview as to the effectiveness of concept mapping for education. They identify studies with random assignment of learners to conditions e.g. Eseiobu and Soyibu [1995], studies in which classes were randomly assigned to conditions [Pankratius 1990, and Czerniak and Haney 1998], studies that utilised extant methods of instruction [Nicoll et al. 2001], studies in which an alternative educational intervention was compared to concept mapping [Spaulding, 1989, Zittle, 2002, Chang et al. 2001] and studies that compared concept maps with other forms of learning material [Rewey et al. 1989], which like the analysis of Horton et al. [1993] again show variances, in the positive effect of concept maps.

2.4.5 Benefits of concept maps

Learners studying in self-regulated environments have to come to terms with an increasingly complex knowledge base, especially as their University career continues. Whilst students presently have the opportunity to reflect upon what they have learnt in each module there are few means through which to link these reflections to each other to ascertain, (a) any misconceptions that they may or may not hold, or (b) links between concepts through which relational links expand their knowledge by identifying facets of knowledge that the student did not previously know existed. Such a scenario, as part of an introductory module, is exacerbated as many students have not yet acquired effective strategies through which to overcome associative cognitive overload and conceptual and navigational disorientation [Bleakley and Carrigan, 1994].

However, whilst there are few options that allow students to make connections and link reflective information there are also alternative assessment techniques and strategies that can and have been adopted to encourage students to consider links across modules for example. Such methods include, amongst others, synoptic assessment, and e-portfolios. Such forms of assessment may help students to make connections between modules, and increase levels of student engagement [see work at Leeds Met [2011], for example e.g. Gorra et al. [2008] and Kyaw and Drummond S [2007]. What is crucial is that the importance of the process of learning as distinct from the outcome of learning is given more attention within this model, Leeds Met [2011].

However, it can be argued that visualisations, such as concept maps, are also beneficial to help learners to cope with subject-matter complexity and ill-structuredness e.g. Holley and Dansereau, [1984] and Jonassen et al. [1993]. Visualisations such as concept maps may help students elicit, co-construct, structure and restructure, elaborate, evaluate, locate and access, communicate, and use ideas and thoughts as well as knowledge about relevant contents and resources i.e. Jonassen et al. [1993]. Therefore, helping students to organise their knowledge is as important as the knowledge itself, since knowledge organisation is likely to affect students' intellectual performance e.g. Bransford et al. [1999].

Durling and Schick [1976] have compared concept attainment across three interactive settings: vocalising to a peer also learning the task, vocalising to a confederate supposedly learning the task, and vocalising to the experimenter who supposedly had mastered the task. If merely verbalising the material was the primary mechanism affecting achievement, then the three conditions should have yielded similar levels of achievement [Webb, 1982]. However, students' vocalising to a peer or to a confederate performed better than students vocalising to the experimenter. This result suggests that the purpose of verbalising is more important for learning than the mere act of verbalising' [Webb, 1982].

Furthermore, describing an individual's or a group's cognitive structure through other techniques such as a spoken narrative, an outline, a written summary, formal and informal conversation, a flowchart etc. is limited in that these techniques are linear and unable to depict the complexity of relationships between concepts and ideas [Fraser, 1993]. Therefore, the process of creating and using the map is as important as the content of the map [Freeman, 2004]. For example, through the actual process of constructing a concept map the individual can also make new connections and recognise concepts which should be added e.g. Fraser [1993].

Computer-based mapping tools have been shown to contribute to foster processes of knowledge communication in several ways. They may, for example, be used to communicate the concept structure of a subject matter and enhance knowledge acquisition e.g. McAleese et al. [1999]. They may also be used as a basis for enabling cooperative work e.g. Jacobson and Levin [1995]. Mapping tools may be useful in promoting coping with a task situation that requires knowledge which is too comprehensive and conceptual views which are too diverse for a single person to manage successfully e.g. Tergan [2003].

Concept maps also provide functions for externalising mental representations of knowledge in arbitrary and visual formats. These representations are not necessarily 2D representations in the form of traditional node-linked based diagrams, with tools allowing for mappings in a hypertext-like format by using sub-maps and links e.g. Alpert and Gruenenberg [2000] and Cañas et al. [2005]. In this way, concept maps have been used in terms of offering navigational support e.g. Jonassen and Wang [1993] and McDonald and Stevenson [1998].

2.4.6 Problems associated with concept maps

Fostering a deep level of learning is very difficult because students do not spontaneously adopt strategies that foster such learning [Sandberg and Yvonne, 1997]. Additionally, some students have difficulty building concept maps and using these, at least early in their experience e.g. Novak [2006b]. As a result, Novak [2002] recognises that even when classroom learning experiences involve hands-on activities to illustrate concepts and principals, many students fail to construct concept and propositional frameworks that are congruent with what scientists or mathematicians currently believe and as such can be considered a problem of faulty conceptual frameworks. Crucially, the facilitation of students' acquisition of powerful and valid conceptual frameworks is not easy. There are innumerable ways to go wrong and no set of traditional instructional strategies that are foolproof.

In the case of a large domain, or of a detailed representation of a domain, a single, concept map can become unmanageable for the user to comprehend, display and manipulate [Cañas et al. 2005]. To facilitate the construction of large representations, CmapTools allows the user to split them into collections of concept maps. To show the relationships between the concepts in the set, the software facilitates the linking of concept maps, enabling the navigation from one map to another. Additionally, the user can establish links to other types of resources (e.g. images, videos, sound clips, text, Web pages, documents, presentations, and other concept maps) that help explain and complement the information in the tool. It is one possibility that large-screens may be useful in alleviating the unmanageability of complex concept maps.

Tan et al. [2006] for example, argue that physically large displays improve performance on spatial tasks, which open up interesting areas surrounding the notion of more immersive environments and their use with concept maps. In their research, they present four experiments comparing the performance of user's working on a large projected wall display to that of user's working on a standard desktop monitor. Results, from the first two experiments, suggest that physically large displays, even when viewed at identical visual angles as smaller ones, help user's perform better on mental rotation tasks. They show through the experiments how these results may be attributed, at least in part, to large displays immersing users within the problem space and biasing them into using more efficient cognitive strategies. In the latter two experiments, they extended these results, showing the presence of these effects with more complex tasks, such as 3D navigation and mental map formation and memory. Results therefore suggested that physically large displays, even at identical visual angles as small displays, immerse users and bias them into adopting egocentric strategies. Furthermore, the effects caused by physically large displays seem to be independent of other factors that may induce immersion or increase performance. For example, even though interactivity and mental aids such as distinct landmarks and rich textures within virtual worlds increase task performance on the tasks tested, they did not affect the benefits that large displays offer to users. In constructing complex workspaces researchers have pursued the use of large displays for collaborative tasks [Chou et al. 2001, Elrod et al. 1992, Raskar et al. 1998, Streitz et al. 1999, and Tani et al. 1994]. Large displays in these settings are easy for all users to see and interact with [Gruimbretiere et al. 2001], providing a conduit for social interaction. Some of these researchers have begun to document performance increases for groups' working on large displays [Dudfield et al. 2002].

2.5 Summary

This chapter has provided a high level introduction surrounding the educational reasoning of concept maps and their usage. It has also explored some of the benefits and problems associated with their use as a pre-cursor to considering how traditional and subsequent natural interfaces may be applied to their use as increasingly technologies are seen as being collaborative in nature. Chapter 3 will now consider how concept mapping tool interfaces have and can be reconsidered in view of these new forms of interaction technologies and the subsequent impact their use has on group dynamics when manipulating mode and configuration of input.

3 Technology - re-imagining conceptual interaction

3.1 Introduction

This chapter introduces and reflects upon existing technologies that support interaction and considers how they have been used to direct the investigation presented within this thesis. These technologies are considered in the specific context outlined in chapter 2 i.e. the consideration of concept mapping and the use of mode and configuration of input in this context. This chapter therefore considers interactive tabletops, input devices and wall surfaces (that include large-screen projections and displays) which may allow for the supporting of collaboration and interactivity in novel ways, beyond that of keyboards and mice e.g. [Fleck et al. 2009] and Pavlovych and Stuerzlinger [2008]. These systems can also incorporate other input devices, e.g. laser pointers, marker pens with screen location sensors or touch sensitive surfaces. The purpose of this chapter is to introduce these technologies when used with large displays and their initial application to concept mapping software. The subsequent investigation of how these devices affect group dynamics are also considered in terms of their configuration and mode of input, with their specific application to conceptual mapping tasks in this context investigated in the following chapters of this thesis.

3.2 Large-screens – environments for interaction

Continued 'advances in display hardware, computing power, networking and rendering algorithms have all converged to dramatically improve large high-resolution display capabilities' [Ni et al. 2006]. As a result, large wall-sized displays are increasingly available within areas that promote creativity and innovation e.g. Lee et al. [2008], Scheible et al.[2006] and collaborative work e.g. Fleck et al. [2009], with such technology recently entering the classroom accompanied by table-top displays e.g. Fleck et al. [2009].

With the proliferation of such displays, research into addressing a fundamental question: 'How do user's benefit from increased size and resolution?' have begun to be addressed. Many researchers 'intuitively believe that large displays automatically outperform small ones' [Ni et al. 2006]. However, it is desirable to ascertain why increased size and resolution may be advantageous (although beyond the scope of this research). As a result, both quantitative and qualitative research has been completed, with the aim of 'demonstrating the relationship between the changing visual effects afforded by emerging technologies and user's' productivity and performance in collaborative and individual work' [see, Tan et al, 2006].

Furthermore, as researchers have begun to investigate both collaborative and individual uses of large-screen displays, new questions, surrounding interaction with and around these larger displays, when using these new interaction techniques have been raised. For example, multi-touch tabletops have been explored for a variety of uses recently, with the aims of the research being the investigation of the potential of these devices and development of new ways of interacting with and around them e.g. [Fleck et al. 2009]. However, it is only recently, that such devices and interaction around them are being considered in the context of education situations, and whether they can facilitate collaboration while carrying out learning tasks e.g. Fleck et al. [2009]. Early investigations, e.g. Do-Lehn et al. [2009] have found that in comparison to an augmented tabletop surface, a traditional interface with a single mouse input led to closer working and more discussion, which subsequently led to greater learning gains. What is important however is that research in this area is only just beginning to consider the collaborative nature of interacting with large-screens. Existing technologies, that have been investigated in this context e.g. Koenig [2010], and Ahlborn et al. [2005], and Shizuki et al. [2006], and Vogt et al. [2004], have already begun to investigate large-screen setups and their use with mice in standardised evaluations e.g. [Oh and Stuerzlinger, 2002]. As such the subsequent sections of this chapter will consider these established methods of interacting with large-screen technology in more depth before considering newer more natural interfaces and their use with large-screens.

3.3 Mode of input and large-screen displays

Large-screen displays have been used in association with a variety of inputs (i.e. laser-pointers, mice, and pens), 'yet none have really emerged as a clear choice for a range of applications and for many there may not be a single best option' [Vogt et al. 2004]. Ha et al. [2006] for example, investigated the effects of different input devices upon on users' behaviour and concluded that direct input methods (stylus, touch) support a greater awareness of intention and action than the indirect method of mouse usage. At the same time, these findings are confirmed by Hornecker et al. [2008] who compared groups of three people using a table-top display against the use of multiple-mice in which the affordances of touch input and body movements resulted in better awareness about (and also more inferences) with other group members.

It is also more than likely that the 'best' 'input configuration for a scenario depends heavily on the task and a range of other factors, with users also adapting their existing behaviour to available technologies in ways that can influence processes and outcomes. As such, it is also possible that input configuration might also influence group behaviour e.g. Birnholtz et al. [2007]. However, there have been few systematic investigations into the effect of single vs. multiple input streams on group collaboration styles and outcomes when using a large, shared display beyond the exploratory study of input configuration and group process in a negotiation task of Birnholtz et al. [2007] and Vogt et al. [2004], who used mice, keyboards and laser-pointers. However, tabletop and wall surfaces and gesture based modes of input support collaboration and interactivity in new ways, with the associated challenge of understanding how users of such systems interact and collaborate when using this technology. Apart from keyboards and mice, these systems can incorporate other input devices, such as laser pointers, marker pens with screen location sensors, touch sensitive surfaces, and wands etc. Similarly, instead of a vertically positioned desktop monitor, collaborative setups typically use much larger displays, which are orientated either vertically (wall) or horizontally (tabletop), or can combine both kinds of surfaces.

Most existing large screen collaborative systems employ touch sensitive screens, pen-based systems, or mice as the primary means for user interaction. These existing forms of interaction will now be introduced here; however, newer ways of interacting with large screens will also be introduced as a means of showing the progression of research in the area of interacting with shared displays for collaborative tasks.

3.3.1 Shareable interfaces

A shareable interface is a generic term that refers to technologies that are specifically designed to enable co-located groups to work on shared systems. They include systems with multiple input devices, interactive touch surfaces, tangible surfaces and tangible interfaces. A crucial question, when investigating such technologies is whether shareable interfaces encourage more equitable participation from group members - given that they are inherently designed to support collaboration. Early investigations have compared different types of shareable interfaces with a control condition of a single user interface (PC with one mouse input). The technologies that have been used were a multi-user tabletop and a tangibles condition e.g. Marshall et al. [2006]. A useful extension of such an analysis might be to determine which mode, or modes offer the most useful way through which to construct concept maps and facilitate knowledge visualisation. Marshall et al. [2006] hypothesised that the more inviting (i.e. least constrained) a shareable interface is the more likely that equitable participation will ensue. Findings from their initial experiment, (where six groups of three participants for each condition took part in a collaborative design task) showed significant differences between these conditions. Surprisingly, Marshall et al. [2006] found that the greatest number of utterances and suggestions made was in the most constrained condition (i.e. the PC with one input device) but on further inspection it was found that these contributions were made mainly by one person. At the same time there was very little switching of roles in terms of who interacted with who or who created the content using the mouse. In contrast, the least constrained, shareable interfaces encouraged the most equitable physical participation. There wasn't, however, a significant difference between the tangibles and tabletop conditions, although there was a number of differences in terms of turn-making, social organisation and planning.

3.3.2 Tangible interfaces

People have developed sophisticated skills for sensing and manipulating our physical environments. However, most of these skills are not employed when using traditional GUI (Graphical User Interface). Crucially, such a situation is increasingly prevalent in the area of knowledge management and the formalisation and construction of conceptual knowledge and understanding.

There is now a growing appreciation that the process of creating content may be more important to learning than the act of merely consuming it e.g. Milne [2007]. In this way, the emphasis of learning technology application is correspondingly shifting from high-quality content delivery to informal content manipulation and delivery [Milne, 2007]. Therefore, with a greater emphasis on informal activities, there will be a need for additional interface requirements. The principal forms of these needs will be discussed in terms of tangible and haptic devices, as well as the next generation of peripherals that are gesture-orientated i.e. Nintendo's WiiRemote.

The main aim of these new tangible interfaces is as described by MIT's tangible media group where the goal is to change the "painted bits" of GUIs (Graphical User Interfaces) to "tangible bits," taking advantage of the richness of human senses and skills developed through our lifetime of interaction with the physical world [MIT, 2007]. As such, MIT and others are designing tangible user interfaces which employ physical objects, surfaces, and spaces as tangible embodiments of digital information. The main aim therefore of such objects, can be considered as being the inclusion of foreground interactions with graspable objects and augmented surfaces, exploiting the human senses of touch and kinaesthesia, which as a consequence (and to a certain extent true of the next generation of peripherals i.e. WiiRemote) raise new questions as to the role of gesture in relation to the interaction with knowledge and its possible influences upon the reinforcement of learning processes.

These new forms of tangible interfaces are systems relating to the use of physical artefacts as representations and controls for digital information [e.g. Ullmer & Ishii, 2000]. As a result, a central characteristic of these tangible interfaces is the seamless integration of representation and control, with physical objects being both the representation of information and as physical controls for directly manipulating their underlying associations. In this way, input and output devices often fall together. On the other hand, digital spaces have traditionally been manipulated with simple input devices such as the keyboard and mouse. Presently, these controls are used to control and manipulate (usually visual) representations displayed on output devices such as monitors, or whiteboards through graphical user interfaces, and separate control from presentation.

Traditionally, in HCI a distinction has been made between input and output, however in tangible interfaces this distinction disappears where:

- In tangible interfaces the device that controls the effects that the user wants to achieve may be at one and the same time both input and output.

- In GUIs the input is normally physical and the output is digital, but in tangible user interfaces there can be a variety of mappings of digital to physical representations O'Malley [2004].

In contrast to GUIs, TUIs (Tangible User Interfaces) provide a much closer coupling between input and output. Tangible interfaces attempt to remove this input/output distinction and open new ways of interaction that ultimately blend the physical and digital worlds. For example, when using an abacus, there is no distinction between 'inputting' information and its representation - this sort of blending is what is envisaged by tangible computing. Therefore, and in relation to concept maps, concepts could physically exist as nodal objects, and be moved around physically by the user. As such it is the representational significance of a tangible device such as a concept in this context that makes it different to a mouse, which has little representational significance (i.e. a mouse isn't meant to mean anything) [O'Malley 2004]. Therefore, tangible interfaces amalgamate control and representation within manipulative objects. Such a scenario is very different from typical desktop systems, where the mapping between the manipulation of the physical input device (e.g. clicking a mouse) and the subsequent digital representation on the output device is relatively indirect.

These representative interactions between different types of tangible interfaces have been distinguished by Koleva et al. [2003] in terms of 'degree of coherence' i.e. whether the physical and the digital artefacts are one common object that exists in both the physical and digital worlds or whether they are seen as separate but temporally interlinked objects. The weakest level of coherence are the general purpose tools where one physical object may be used to manipulate any number of digital objects - i.e. a mouse which controls several different functions [see Koleva et al. 2003] and the strongest level of coherence is where the physical and the digital representations appear to be the same object e.g. an example in the world of tangible computing is the illuminating clay system [Piper et al. 2002].

Of course, there are a number of emerging frameworks which have been applied to tangible systems, including the use of physical objects as tokens to access digital information e.g. Holmquist et al. [1999], the use of generic physical objects as containers to move information between devices e.g. Ullmer et al. [2000] and tangible interfaces where physical artefacts are used to both represent and control digital information e.g. Ullmer and Ishii, [2001] and Marshall et al. [2003]. To date, most research has focused on technological development and the construction of descriptive taxonomies e.g. Ullmer and Ishii [2000]'. Crucially, whilst there have been some attempts to link tangible interaction with philosophical phenomenology [Dourish, 2001], theoretical underpinnings of the learning and other cognitive benefits of TUIs, that have been empirically tested, are distinctly lacking [Marshall et al. 2006]. Therefore, theoretically-grounded accounts and empirically-based studies are now needed to better understand how tangible interfaces actually work. These should explore whether or why tangible interfaces might promote interactive benefits, and which associative features of tangible interface designs might be associated with these benefits and in which situations. It is also conceivable therefore, that such an undertaking should apply to the use of gesture-based peripherals which allow gesture-based interactions.

3.3.3 Laser pointers

Laser pointers as input devices have been investigated in several large screen display based setups e.g. Ahlborn et al. [2005], Olsen and Nielsen [2001], Shizuki et al. [2006], Vogt et al. [2004] and Birnholtz et al. [2007]. These devices offer a number of advantages when interacting with large screen-displays, with a principle advantage being that they allow close-range manipulation as well as the ability to work at a distance. Additionally, laser pointers are straightforward to use, and require minimal training to be able to use them. At the same time, using a laser pointer from a distance reduces obscuration of the screen by hands, fingers, or pens. Research in this area has concentrated on their comparison to mice e.g. Oh and Stuerzlinger [2002], Myers et al. [2002] and Pavlovych and Stuerzlinger [2008], with aspects of collaboration considered by Vogt et al. [2004] and Birnholtz et al. [2007] which are discussed in relation to the principal areas they address (those of configuration of input) in section 3.4 of this chapter.

3.3.4 Pens/ wands

Gruimbretiere et al. [2001] have described interaction techniques for direct pen-based interaction on the Interactive Mural, at Stanford University. The techniques were designed for digital brainstorming, with the pen-based tool used to support free hand, high-resolution materials. Cao and Balalrishnan, [2003], through the use of VisionWand (a passive wand tracked in 3D), have also explored a further device. A set of postures and gestures were developed to track the wand and enable command input through a pie menu. The concept was interesting since a wand tracked in 3D with computer vision techniques enabled higher degrees of freedom, hence the potential for richer interaction styles.

3.3.5 Gesture based devices

LaViola et al. [2004] have developed a set of novel input devices for CAVE-based virtual environments. They employ hand gestures, such as pointing with a tracked, finger-worn sleeve or foot gestures, such as tapping toes or heels on a map with a foot-worn slipper for navigation. At the same time Vogel et al. [2005] have also used hand gestures to indicate typical user interface actions such as point-and-click when working at a distance from the display surface. Additionally, the Interactive Workspaces Project [Johanson et al. 2009] have explored interface possibilities for people working together using large displays. They integrated a variety of interaction devices and techniques including wireless multimodal devices. Other similar work combining interaction devices with display walls have been identified by Ni et al, [2006], Ringel et al. [2001], Rekimoto [1998], Myers [2000]; Ishii et al. [1994], and Olsen and Nielsen [2001]. Whilst these methods of interaction have begun to be investigated in the context of large displays, there does not seem to be any consensus on which circumstances these different methods are appropriate to. This is also true as to how these different modalities affect the user's experiences especially in a collaborative, gesture-orientated and conceptually focused setting.

3.3.6 The WiiRemote

The WiiRemote controller is now described as a means through which pointing and gestures have been combined into a tangible device that provides haptic feedback.

The WiiRemote is the primary controller for the Nintendo Wii console. A main feature of the WiiRemote is its motion sensing capability, which allows the user to interact with and manipulate items on screen via gesture recognition and pointing through the use of accelerometer and optical sensor technology. The WiiRemote has the ability to sense acceleration along axes through the use of an ADXL330 accelerometer see Figure (3.1) which, when combined with the PixArt optical sensor, allows the controller to determine where the WiiRemote is pointing.

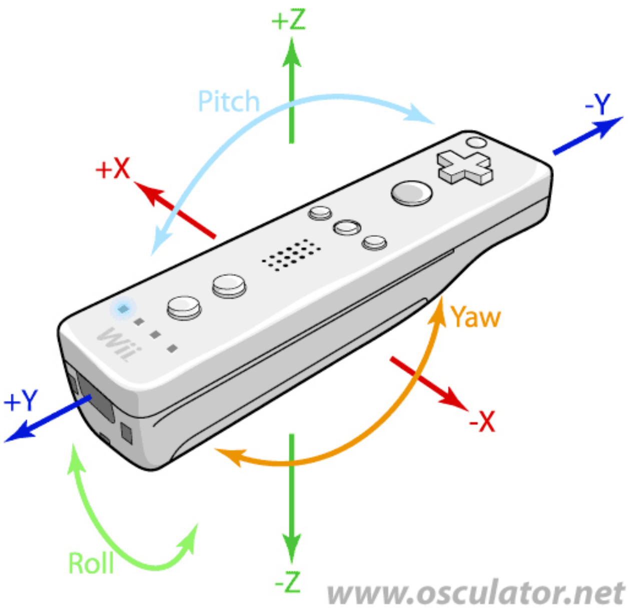


Fig 3.1: WiiRemote and the degrees of movement generated through the accelerometer.

Use of the Sensor bar allows the WiiRemote to be used as an accurate pointing device up to five meters away from the bar. Recently, the Wii MotionPlus has been released as an expansion device that allows the WiiRemote to more accurately capture complex motion. As such, MotionPlus uses a tuning fork gyroscope, [Nintendo, 2008] which supplements the accelerometer and Sensor bar capabilities of the WiiRemote, enabling controller motions to be rendered identically on the screen in real time.

Further developments planned include The Wii Vitality Sensor which is used as a fingertip pulse oximeter sensor that connects through the WiiRemote. More details concerning the Wii Vitality Sensor will be showcased during Electronic Entertainment Expo 2010.

The Nintendo WiiRemote interface reflects the recent trend of introducing novel interaction techniques by providing motion sensing capabilities that are integrated into a tangible remote control device. Using the WiiRemote allows interaction within the range and accuracy restraints provided by the accelerometer based sensing technology. This form of interaction offers a greater freedom of body movement than single-user GUI-style mouse in front of a computer screen interaction, and offers multi-user gesture based experiences beyond the point and clicking of mice and the pointing of laser pointers.

It has been argued that the direct one-to-one relationship between the virtual action on the screen and the real-world action of the user reinforces the invisibility or transparency of the interface, rather than redirecting the user's reflexive awareness towards their own body e.g. Levisohn. [2007] and Bolter and Gromala [2005] where the WiiRemote can be used to explore the possibilities for constructive cooperation between interactors e.g. Lee et al. 2008]. Their WiiArts project attempted to explore the possibilities of using a console for creating collaborative, active, expressive and creative art experiences. It uses pre-existing sensing technologies provided by Nintendo's WiiRemotes and a wireless sensor bar, with limited interactions based on the X-Y axes movement with WiiRemotes. For example, their art piece 'Beneath', allows the WiiRemote to be controlled as a flashlight or magnifying lens that viewers can use to expose portions of the images hidden beneath the dark layer of the screen, with the revealing experience evoking emotional responses from the viewers. At the same time, the 'WiiBand' allows three users to create music using WiiRemotes, allowing for the control of the

Y-axis (pitch) changes the volume of the sound and the control of the X-axis (yaw) changes the pitch of the sound. With a three-person interaction this becomes a real-time musical performance, like a band. Through introducing these interaction techniques, Lee et al. [2008] highlight the potential of these mediums to provide new forms of interaction, however they offer no discussion of what impact these interactions have on the users' collaborative experience of these art experiences or what types of interactions for example enable them to collaborate effectively to create music.

Crucially, a number of researchers have also adopted the WiiRemote for other purposes i.e. for gesture recognition based applications e.g. Schlömer et al. [2008], robot control e.g. Lapping-Carr et al. [2008], 3d spatial recognition e.g. Chow [2009], and in many other areas see [Hay et al. 2008, Deligiannidis and Larkin, 2008, Attygalle et al. 2008, and Schou and Gardner [2007], amongst many others. The main advantage of the WiiRemote is that it combines an infrared sensor with an accelerometer, and a variety of buttons in a single device, offering pointing and gesture based input. This makes the device very flexible as the data provided by the accelerometer can be interpreted in a variety of ways depending on the intended context e.g. Chow [2009]. This extensibility has prompted researchers to apply the WiiRemote to large screen technology for example. Previous work in this area has demonstrated that the WiiRemote can be used as a control device for large displays e.g. Pelling et al. [2009] and Bellucci et al. [2010], yet like Lee et al. [2008], this work does not consider how the configuration of these forms of input and the mode themselves impact upon social dynamics in small groups when interacting with concept maps.

3.3.7 Multi-touch shared surfaces

With the recent development of tabletop surfaces, people, when interacting in small groups of people around them, are offered new possibilities through which to interact and collaborate. Potentially, tabletops allow groups of people to manipulate a shared display simultaneously and offer new possibilities for understanding how small groups interact when using these devices. For example, Fleck et al. [2009] have revealed that what might be considered undesirable or harmful interactions and intrusions in general collaborative settings might indeed be beneficial for collaborative learning. Yet little is known about the type of interactions that occur in these settings or how they affect group dynamics. Previous research has suggested that this technology is enjoyable to use, promotes playfulness and can lead to learning e.g. Do-Lenh et al. [2009], Harris et al. [2009], Piper et al. [2009] and Rogers et al. [2009]. However, recent studies on collaboration around tabletops have shown the effects to be small or insignificant when compared with other technologies e.g. Harris et al. [2009], and also in the realm of concept mapping e.g. Do-Lenh et al. [2009],

Rogers et al. [2009] have shown how physical actions and types of discussion are indicative of productive collaboration. However, Fleck et al. [2009] claim that ‘little is known about the relation between physical actions and aspects of discussion in relation to collaborative learning’. This is also true of the types of interactions displayed when interacting with shared displays in this way. As a result, Fleck et al. [2009] present the Collaborative Learning Mechanisms (CLM) framework, which they use to consider both verbal and physical aspects of children’s collaboration as they complete a design task around a multi-touch tabletop. However, within the context of education, the potential of these technologies to enable groups to simultaneously touch and manipulate a shared tabletop interface is only just beginning to be researched in terms of whether they can facilitate collaboration. For example, research has looked at the potential of tabletops to support collaborative exam revision e.g. Piper et al. [2009] and learning with a mind mapping application Do-Lenh et al. [2009]. At the same time, Cappelletti et al. [2004] found that ‘StoryTable’ encouraged groups of children to work together to develop narratives with high cohesion. In this previous research on collaboration, in the context of learning activities, improved learning outcomes have been shown by pre- and post –test scores, which have been reported as evidence that effective collaboration has occurred using the particular technology. However, Fleck et al. [2009] argue that this approach is of limited value in telling us ‘how collaboration occurs or why it is effective'. As such, an alternative approach is to consider aspects of the process of working that suggest enhanced collaboration was occurring: for example: the equity of participation and the amount and type of discussion occurring, or the type and amount of interaction.

Rick et al. [2009] and Harris et al. [2009] have reported on whether multi-touch was beneficial for learning compared with a single touch interface. They found that there was more task-focused talk in the multi-touch condition and more turn-taking talk in the single-touch condition. No differences were found between these conditions in verbal equity of participation, or physical equity (in terms of how many touches each child made or in the distribution of these touches). This research considered both talk and physical interactions, the findings, as discussed above, were based on how much of the various types of talk occurred in each condition and the number of touches by each participant – not how they related directly to each other during collaboration. Fleck et al. [2009] aim to address this problem by presenting their framework to consider the role physical actions and gestures play in complementing discussion in these instances. As a result, they found that there were both physical and verbal aspects involved in children's coordination of their collaboration around the tabletop. For example, children maintained joint awareness, essential for effective collaborative learning, both by watching and listening to other's suggestions, and responding likewise. They also found that the children used verbal narrations to keep others informed of their own actions and intentions. Furthermore, they found evidence to suggest that features of the tabletop and task design led to participant's regular intrusions into each other work, which may have encouraged joint awareness. At the same time Tang et al. [2006] found that some accidental interactions around a multi-touch table triggered periods of closer working pairs of adults working on map-based route planning tasks, and Hornecker [2005] also found the system restraints requiring coordination and sharing of resources, whilst having negative task effects and causing breakdowns, actually fostered collaboration.

There have been several studies concerning the impact of tabletop usage and its subsequent impact on group process and performance. Initially, Ryall et al.

[2004] reported on the effects of group size and table size on task performance. Rogers and Lindley [2004] have also shown that small groups were more comfortable working around an interactive tabletop than in front of a pc or a vertical display. At the same time Rogers et al. [2009] found that group process and performance may depend to a large extent on the modes of interaction. Laser pointers as opposed to WiiRemotes are different interaction modes of input. Ha et al. [2006] for example investigated the effects of different modes of input devices on users' behaviours and found that direct input methods (stylus, touch) support a greater awareness of intention and action than the indirect method (mouse). Such findings were also found by Hornecker et al. [2008] who concluded that touch input and body movements resulted in a better awareness about and with other group members.

A more recent development in tabletop design and in the context of concept mapping is the development of augmented tabletops. An augmented tabletop is 'a table surface that works both as an input device and a visual feedback display to users'. As a result, augmented tabletops offer the potential to facilitate collaborative scenarios, in which multiple users work concurrently on the same task. Do-Lenh et al. [2009] used a tabletop system that enabled students to interact via paper pieces as well as using direct touch and compared the system's ability to support student's performance to the traditional computer system. They focused on measuring the differences in learning outcomes at individual and group levels between students using two interfaces: traditional computer and augmented tabletop with tangible input. They found no significant effects of the interface on individual learning gain, where groups using the traditional computer interface learnt significantly more from their partners than those using the tabletop interface. Further analysis showed that there was an interaction effect of the condition and the group heterogeneity on learning outcomes.

In addition, Do-Lenh et al. [2009] argue that hardware setup also plays a role in group behaviour when interacting with tabletops, with group dynamics possibly affected by freedom of movement during experimentation e.g.

Marshall et al. [2008]. Do-Lenh et al. [2009] also find that there is the dominance of more knowledgeable peers in the computer condition and a richness of interaction styles and strategies in the tangible condition. As a result, the collaboration strategies followed by the groups differed depending on the conditions. Collaboration in the tabletop condition involved a mix between explanation, group work and individual work with group members shifting back and forth between these modes. The collaboration in the computer based condition was much more coordinated with the groups having an implicit work division, e.g. a person using a mouse to create a link and a person typing on the keyboard. As such, there were implicit private spaces that their partners were reluctant to reach into, following the proposition that people are usually comfortable working at arm's length e.g. Ryall et al. [2004].

3.4 Collaborating (configuration of input) and large-screen displays

Enabling group work through collaboration is important in computing. However, it has been suggested that very little is known about the affordances of collaborating with multiple pointing devices e.g. Vogel et al. [2005]. As such, input devices are frequently designed to be used in the context of single users, so usability concerns focus on how the devices can improve single user interaction e.g. Vogt et al. [2004]. Consequently, as computing becomes more collaborative in nature, researchers must also consider the impact devices will have on communication and collaborative work processes. While user interfaces for standard desktop displays have been developed over a few decades, there has been relatively little work on interfaces for large format displays [see, Ni et al. 2006]. However, users of such systems cannot fully exploit the benefits of large high-resolution displays by merely presenting a huge amount of information. Accordingly researchers argue e.g. Ni and Bowman [2005] that users should develop usable and useful input devices and interaction techniques that accommodate distinct characteristics afforded by emerging technologies [e.g. Nintendo's WiiRemote]. Ni et al. [2006] provide an overview of present user interfaces for large displays. Also see

Cao and Balakrishnan [2003], LaViola et al. [2004] Malik et al. [2005] and Vogel et al. [2005].

Large displays, arguably, allow for novel forms of interaction involving more users and/or more information than traditional displays. Example tasks where such functionality might be useful include collaborative brainstorming, working with 2D and 3D design sketches and collaborative writing [see, Birnholtz et al. 2007]. Crucially, the traditional interfaces of keyboard and mouse are not always the most suitable forms of input device for interaction with large displays; neither are they necessarily the most engaging. One of the obvious drawbacks is that both of them require a stable surface to operate. However, when users work up close to a large display and step back and forth, it is not practical to hold a keyboard or a mouse while effectively manipulating the contents on the display space [Bowman, 2005].

However, little is understood as to how such input devices inform the processes of collaboration and group process in small groups when they use such modes of inputs and even less is known when using variant modes of input i.e. no gestures or gestures. This is despite initial evidence suggesting that groups choose to collaborate differently depending on whether they use multiple mice or multiple laser pointers with the suggestion that mice and laser pointers can be used to support different aspects of collaboration and can influence interaction with shared displays e.g. Vogt et al. [2004] and Birnholtz et al. [2007].

There has however, been some prior study of groups interacting with a shared smaller display using varying combinations and types of input modalities, largely in the area of Single-Display Groupware (SDG) e.g. Stewart et al. [1999] and Tse et al. [2004]. However, there has been little investigation into the impact of input modality and configuration on group process, especially in the context of conceptual mapping and gesture-enabled devices. Critically, for many years, pointing devices such as mice have been evaluated in the context of interactive performance (i.e. reliability, precision and accuracy) as they might be used by single users [see, Vogt et al. 2004]. However, more recent investigations have focused on the role that input devices play in group situations. As such, Stewart et al. [1999] introduced the SDG model for supporting collaborative work between co-present individuals and reported that children engaged in an educational task subjectively preferred two mice over a single mouse.

Inkpen et al. [2005] investigated the social and productivity benefits of supporting collaborative behaviour using multiple mice. Stanton et al. [2003] evaluated multiple mice and tangible interfaces for encouraging shareable, co-present interaction with children in a desktop environment. Such studies provide some evidence to suggest that choice of input technique can impact group performance and satisfaction, but this question has not been investigated in the context of gestural and non-gestural interaction and their application to the co-construction of conceptual maps. Exploratory work on tangible interfaces in general has suggested that they might be particularly suitable for engaging children in playful learning [Price et al. 2003] and that novel links between physical actions and digital effects might lead to increased engagement and reflection [Rogers et al. 2002]. However, it remains unclear which elements of tangible interface designs are critical in supporting learning activities and which are incidental; the roles played by the physical and gestural and digital elements in different designs remain to be mapped out e.g. Marshall [2007].

Interestingly, DiMicco [2004] has studied the impact of large displays on group conversation, but did not focus on input configuration and modalities; neither did they consider the impact of such modalities on student levels of engagement and interaction. Vogt et al. [2004] have however compared group performance with a mouse versus a laser pointer when completing a maze task, but they did not examine influence on group behaviour beyond the time it took to complete the task. Birnholtz et al. [2007] have suggested in a mixed motive negotiation task under two conditions- a single shared mouse and one mouse per person- that the multiple mouse condition allowed for more parallel work, but the quality of discussion was higher in the single mouse condition. Moreover, participants were more likely to act in their own best interest in the multiple mouse condition. Whilst their focus refers to particular differences between the two input configurations and their influence upon negotiation and group processes and outcomes, it remains to be determined how such configurations may be affected by mode of input i.e. gesture-orientated or non-gesture enabled and the subsequent impact.

In their research Birnholtz et al. [2007] focus on the study of groups performing a negotiation task on a shared high-resolution large display under two input configurations: single mouse and multiple mouse (one per user). They focus, in particular, on differences between these conditions in individual influence on negotiation, and group process and outcomes. Their study also focused on using traditional mouse input, with the perceived advantage that users could be comfortably seated and at a distance that allowed them to view the display in its entirety. Less traditional methods, which are often performed at a distance, include freehand pointing Vogel et al. [2005], Vogt et al. [2004] and multi-finger gestural input Malik et al. [2005].

Such techniques may be useful for informal interactions with ambient displays or for high degree-of-freedom tasks. However, these are less likely to be useful for more typical tasks such as creating or editing presentations or documents. It remains therefore unclear as to what techniques are best suited for multiple users of large displays e.g. Birnholtz et al. [2007]. Such a statement raises some interesting questions in the context of this research. If ‘new tools are needed to support informal learning activities, in particular, processes associated with concept development' [Milne, 2007] does mode of input and configuration affect group processes when completing conceptual tasks that are designed to aid the discovery and co-creation of knowledge rather than the formalisation of knowledge?

Therefore, appropriate input devices are necessary for engagement to be experienced i.e. Lindley et al. [2008]. Lindley et al.'s 2008 study investigated the comparison of the use of ’Donkey Konga bongos’ (bongos developed by Namco for use with the game Donkey Konga for Nintendo) with a standard controller to examine how affording motion through an input device affects social interaction. Social interaction was found to be significantly higher when the bongos were used, but this did not detract from engagement. Instead, engagement was found to increase when body movement was afforded. Unfortunately, the collaborative characteristics of input devices are often ignored, yet input devices such as the WiiRemote are designed to be used with other input devices and offer tremendous possibilities in the context of large displays and conceptual knowledge construction in small groups. These possibilities are therefore explored in the creation of WiiConcept in Chapter 4 of this thesis.

3.5 Application to concept mapping

Higher Education Departments are being encouraged to plan and deploy learning technologies ‘that encourage and support interaction as a fundamental principal of moving into the 'Interaction Age,' where the fundamental need is to promote and support interaction [Milne, 2007], simultaneously with the processes of learning. Additionally, however, the processes of interaction have increasingly been analysed in the context of large-screen technology. As such, a number of interaction techniques have been investigated for large displays including natural gestures, voice recognition, multi-handed interaction techniques and methods to improve the reach of the user. Accordingly, these techniques show promise, but they need to be evaluated for specific tasks in order to gain a better understanding of how effective they are for interacting with large displays [e.g. Ni et al, 2006], especially in terms of how they can facilitate and aid the construction of knowledge by engaging and encouraging interaction between students and the impact, if any, on group processes and outcomes. Therefore, large high-resolution displays present a number of interaction challenges not well addressed by traditional input devices (represented by keyboard and mouse) e.g. Doug and Bowman [2005]. This is despite evidence suggesting that physically large displays improve performance on spatial tasks [e.g. Tan et al. 2006]. Therefore, it has been identified e.g. Milne [2007] that new tools are needed to support informal learning activities (especially in terms of interaction with large displays), in particular, processes associated with conceptual development. Crucially, 'some of the most commonly used applications- such as office productivity suites, Web publication tools, CAD suites, and media editing applications- are designed to aid the formalization of knowledge rather than its discovery and co-creation' [Milne, 2007].

The lack of experiential and kinaesthetic learning in an educational setting is beginning to be explored with the movement towards interaction in terms of physical and virtual learning spaces, tangible interfaces, natural interaction and new generations of peripherals that emphasise kinaesthetic movement, haptic feedback and gesture-based learning. Crucially, the area of significant promise that has been identified within this thesis and by Milne [2007] appears to relate to the interaction with and representation of knowledge, where new tools are needed to support informal learning activities, in particular processes associated with concept development. Therefore, the subsequent discussion of technology to promote interaction will first introduce traditional technological approaches to conceptual methods of envisioning knowledge. The discussion will then consider some of the new and more established and emerging technologies and their potential uses with concept maps as well as understanding how controller configuration and mode of input impact upon group dynamics and levels of interaction when concept mapping using these new forms of interaction.

Crucially, there is no consensus on how users should interact with large displays when concept mapping. Whilst the ‘best’ input configuration for a scenario likely depends heavily on the task and a range of social factors e.g. Birnholtz et al. [2007], it has also been shown repeatedly that users adapt their existing behaviour to available technologies in ways that mapping can influence process and outcomes e.g. Barley, [1990], Olson and Olson [2001] and Ranjan et al. [2006]. Thus, it is probable that input configuration and mode of input might also influence group dynamics when concept mapping. Nonetheless, there has not been a systematic investigation into the effect of single vs. multiple forms of input and non-gesture vs. gesture usage, on group interaction styles when using a large shared display when concept mapping.

3.6 Existing technological approaches to concept maps

Concept mapping software falls largely into three main categories: software specifically designed for concept mapping, software for mind mapping/concept mapping (where no clear delineation is made between the two) or it forms part of a wider diagram drawing package (examples of all of these software types will be discussed here shortly). As such there are numerous concept mapping software packages available; however, this discussion concentrates on the use of collaborative, synchronous, co-located concept mapping in the context of large screens, with a brief consideration of other concept mapping software.

Crucially therefore, whilst much traditional concept mapping software sees collaboration in terms of sharing the same screen on several computers or asynchronously across the internet e.g. IHMC CmapTools, the consideration of concept mapping within this chapter looks at collaboration in terms of *collaboration in interaction* with concept mapping being carried out through natural interfaces that promote play. As such, the discussion describes the state of the art modes of interaction that are possible with concept maps in general, but, more particularly with their simultaneous use with large screens which is the focus of later chapters of this thesis.

Khamesan and Hammond [2004] provide an excellent overview of concept mapping and technology used in conjunction with concept maps. Within this overview, they identify four different steps which can be recognised in the technology used to create concept maps. These stages in the development of concept map technology are:

Step one: Concept maps created via paper and pencil, requiring a lot of time and effort both from students, for creating and revising, and from teachers, for evaluating;

Step two: The arrival of personal computers and subsequent software developed for creating concept maps allowed students and teachers to construct, modify, maintain and analyse concept maps more easily.

Step three: The third step extended the use of concept maps within hypertext and hypermedia.

Step four: Finally the development of the internet resulted in developments within web-based environments, with research focused on web-orientated concept maps with synchronous and asynchronous communicative facilities.

It is within this model that an additional step into the future should be included, to include modes of technology which are in the early stages of investigation or have as yet not been investigated. This step that should be included, but not originally described by Khamesan and Hammond [2004] might be as follows:

Step five: The fifth step embraces, what Milne [2007] calls 'The Interaction Age' and its imminent rise, which in tandem with Human Centred Design, will facilitate new forms of interaction, but in the context of this thesis, the emphasis focuses on concept maps. Such interaction modalities will embrace natural interaction through multi-touch sensitive displays, and tangible objects or tools.

3.6.1 Traditional collaborative concept mapping software

There are some 350+ concept mapping, mind-mapping, activity mapping, diagramming and idea support software tools [Software for mind-mapping and Information Organisation, 2010], with some forty eight entries for concept mapping tools alone. Perhaps the most well known concept mapping software is the CmapTools program from The IHMC (Institute for Human and Machine Cognition), where collaboration with this concept mapping software is through the use of server orientated shareable concept maps, manipulated via traditional input methods such as the mouse and keyboard.

Such a trend is also true of other major commercial concept mapping software such as that constructed by Inspiration Software Inc. (see Figure 3.2) whereby the diagramming environment allows the user to create bubble diagrams, flow charts, concept maps, process flows and other visual representations where everybody works on the same document, contributing, posting comments, and viewing changes via the Internet.

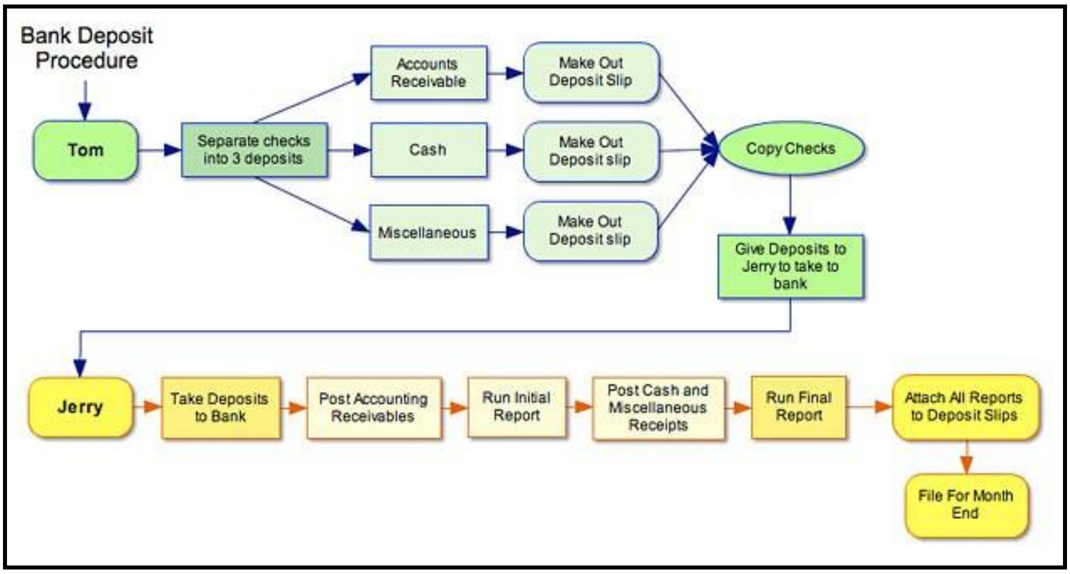


Fig 3.2 Example concept map created in Inspiration concept mapping software.

What is clear about the focus of this type of software is the integration of collaboration across site and that collaboration is synchronous. However, new technologies allow for the development of new forms of interaction with concept mapping collaboratively in the same location and research is moving to reflect this change in focus.

3.7 New approaches to interacting with concept maps and concept map like visualisations

3.7.1 Table top displays and concept map software

Recently, concept mapping software has been developed and considered in the context of its use with multi-user table-top display devices. These methods consider concept mapping software through multiple users, beyond that of mouse and keyboard, in the context of often large-screen based environments. Various tabletop systems have been proposed with different input modalities for example, users of such systems can interact with the virtual objects on the table using mouse or multi-mice e.g. Muller-Tomfelde and Schremmer, [2008], and their own hands directly e.g. Baraldi et al. [2008]. In the particular area of concept mapping there are two introductory adaptations for use with concept mapping described here e.g. Baraldi et al. [2008] and Do-Lenh et al. [2009].

For Baraldi et al. [2008] concepts and relations can be moved on the table surface by grabbing their labels with the two-finger gesture. Then, once grabbed, the object can be controlled only by the user that started the action. The object colour indicates whether the object is engaged or not [Baraldi et al. 2008]. As the gesture is changed the action is finished and the object is positioned in the final location on the screen. Relations are created by taking a Concept with a single-finger gesture and moving the arrow until it collides with another Concept (see Figure 3.3).

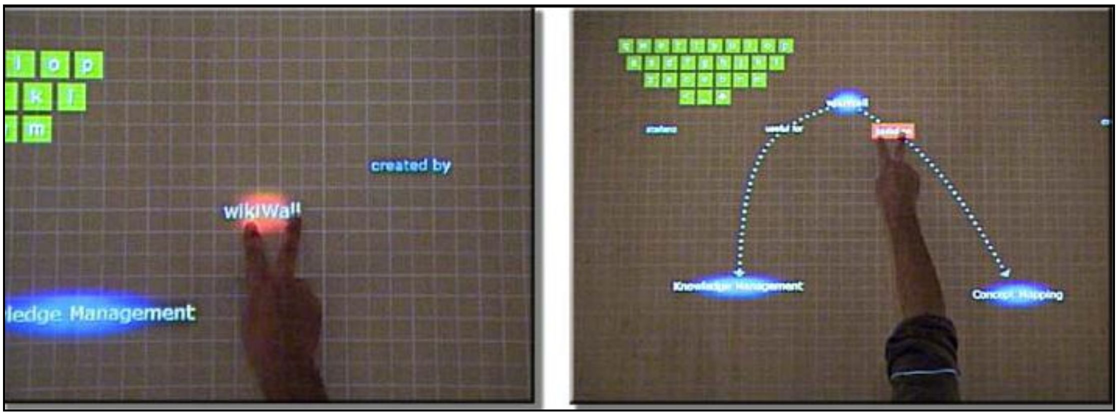


Fig 3.3: Natural interface for table-top concept mapping [Baraldi et al. 2008].

Baraldi's application allowed users the ability to manipulate the contents of a wiki as a visual concept map using a tabletop as a means of providing more natural interaction. As such, the principal aim of their research was the construction and implementations of this software see Baraldi et al. [2008].

In contrast, for Do-Lenh et al. [2009] their aim was to explore the effect of augmented tabletop environments' impact on students' outcomes in an expressive learning task, compared to those using a traditional single mouse interface as a baseline condition. They used a tabletop system that enabled the participants to interact with their augmented system via paper pieces as well as their bare hands (see Figure 3.4).

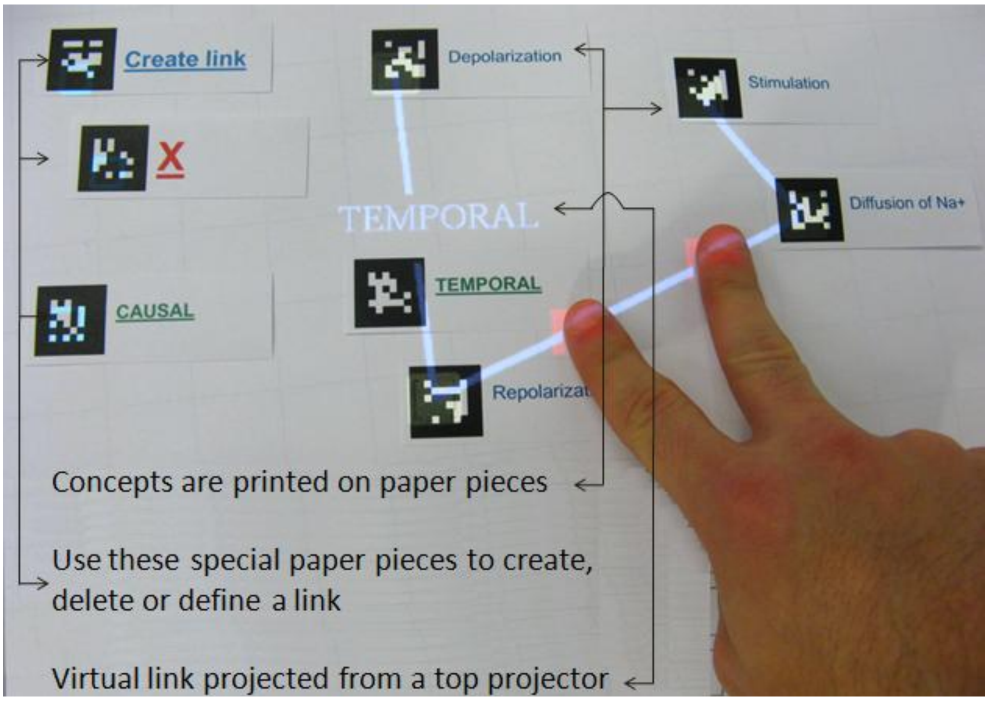


Fig 3.4: Participants used the tabletop interface with physical papers and fingertips in Do-Lenh et al. [2009].

The main focus of their research question was to what extent did the tabletop interface affect the collaboration between students and their learning outcomes, comparing the 'relative educational values of [the] tabletop setting compared to single-mouse configurations' [Do-Lenh et al. 2009]. The two experimental conditions were: (1) the tabletop condition in which the participants used the augmented tabletop display) and (2) the computer condition, in which they built concept map using a computer with a single mouse and keyboard. Eight groups were assigned to each condition.

They found no significant effects of the interface on individual learning gains. However, they did find that groups using traditional computer based interfaces learnt significantly more from their partners than those using the tabletop interface see [Do-Lenh et al. 2009]. There was also an interaction effect of the condition and the group heterogeneity on learning outcomes. Do-Lenh et al. [2009] have therefore provided an introduction to a specific multi-user technology, and have used it to compare its use when completing a concept map with tabletop and traditional computer interface of mouse and keyboards. As a result, when considering the impact of their experimentation on the overall concept map, in the computer condition, participants created concept maps with an average of 23.88 links, while in the tabletop condition, concept maps had 24.88 links on average, not a significant difference by t-test, $t(14) = -.52$, $p > :05$. When checking the number of concepts that are connected to four or more other concepts, they found that groups using the computer created significantly more high-degree nodes than groups using the tabletop interface (Wilcoxon test, $W = 56$; $p = .01$). Their findings were similar to that of Hornecker et al. [2008] and Rogers et al. [2009] that argue that tabletops should be adopted when there is an emphasis upon concurrent physical manipulations.

As such, Rogers et al. [2009] for example, argue that computers designed for single use are ‘often appropriated sub-optimally when used by small collocated groups’. They investigated whether shareable interfaces, (devices that are designed for more than one person to interact with, can facilitate more equitable participation in collocated settings compared with single user displays. To do this they conducted an experiment that compared three different Shared Information Spaces: a physical-digital set-up (least constrained), a multi-touch tabletop (medium), and a laptop display (most constrained). Statistical analyses showed there to be little difference in participation levels between the three conditions other than a predictable lack of equity of control over the interface in the laptop condition. However, detailed qualitative analyses revealed more equitable participation took place in the physical-digital condition in terms of verbal utterances over time. Those who spoke the least contributed most to the physical design task. These findings are discussed at length in the context of their conceptual framework which should not be disassociated form their work and the reader is invited to consult these findings in their original context for more in-depth consideration see [Rogers et al. 2009].

In summary, from this introduction to concept mapping software, with table top displays and their use with concept mapping there is clear research movement towards creating concept mapping software for use with new forms of interface e.g. Baraldi et al. [2008] to Do-Lenh et al. [2009] and their subsequent consideration of group tasks when collaborating around large tabletop displays in small groups. Whilst Do-Lenh et al. [2009] take into account the application of tabletop displays to an expressive collaborative task there are other emerging devices that lend themselves to usage with large-screen displays e.g. Stasche [2008] and the initial use of gesture based devices described in section 3.7.3. However, before introducing Stasche's work the concept 'gesture' will be introduced in section 3.7.2.

3.7.2 The role of gesture in interaction

Kendon [2004, p.1] refers to gestures as occurring when humans are 'in co-presence, [and] continuously inform one another about their intentions, interests, feelings and ideas by means of visible bodily action'. Therefore, how 'people arrange their bodies and how they orient them and place them in relation to each other or to features in the environment, provides important information about how they are engaged with one another and about the nature of their intentions and attitudes' [see, Kendon, 2004, p.1]. As such 'gesture' 'is a label for actions that have the features of 'manifest deliberate expressiveness', that are directly perceived as being under the guidance of voluntary control and being carried out for the purposes of expression, rather than in the service of some practical aim' [Kendon, 2004, p.1].

Therefore, gestural acts can be delineated and defined in a number of ways i.e. facial gestures or empty hand gestures. However, in the context of gesture usage here; the gestural movements associated with tangible devices are the result of these device objects as an extension of the hand that is employed for the gestural act [Stasche, 2008].

As the focus of this thesis is to investigate the use of mode and configuration of input on group dynamics when concept mapping (as highlighted throughout this thesis) the mode of input used was a tangible device. Based on the existing work of Stasche [2008], (who identified gesture sets for usage in the context of individual hand –held gesture based devices) gesture sets had initially been proven to be useful when mind-mapping with large screens (see section 3.7.3 for an introduction to Stasche). However, no investigation into their usage in the context of collaboration and their affect on social dynamics when using such devices with a large display had occurred. As a result, a gesture is situated in the context of these devices as the method of their creation. A gesture therefore, is associated with a characteristic pattern of incoming accelerometer signal data (an accelerometer is a device detecting the acceleration in all three dimensions when an external force exerts on it) with the device used in this case being a WiiRemote. In this context, a gesture describes an ordered, finite series of three-dimensional acceleration vectors with an explicit start and an explicit end.

The accelerometer based data, received from the movements tracked by this controller formulate the gesture used by the user. The user of a WiiRemote therefore can begin a gesture e.g. by drawing a circle, with the gesture complete, the recording process is finished, and the user ends the recognition process. The user can then repeat the gesture by re-creating the gesture that they initially recorded. An example of this process is summarised in Fig 3.5, whereby a gesture is created such as a square or a circle. The gesture may then be re-created, by drawing the square or circle physically in a 3-d space and trigger any action in the digital interface associated with that particular gesture created in the physical world.

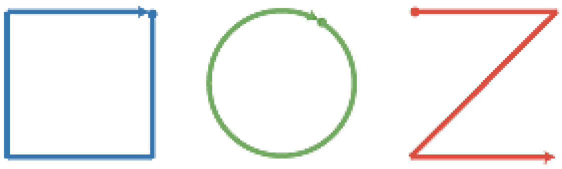


Fig 3.5: Examples of gestures.

Therefore, in this context, gestures are not static in that the gesture needs to be actively created and deployed by the person using the tangible device (WiiRemote). The information about the gesture movement is sensed by the accelerometer located within the device and subsequently interpreted and the associative action completed in the software system. Research associated with gestural interaction employing such devices has been reported for laser or infra-red emitting devices [Chen and Davis, 2002, and Wilson and Shafer, 2003], passively tracked devices [Cao and Balakrishnan, 2003] and portable devices i.e. smart phones and game controllers [Nintendo 2007]. However, there has not been an investigation of its application and incorporation with concept mapping when using multiple controllers in this way, which led to the construction of the WiiConcept software in Chapter 4 of this thesis.

3.7.3 Mind Maps, gestures and large-screens

Stasche [2008] has initially investigated the feasibility of using gesture sets with mind-mapping tasks with individuals when constructing mind-maps with large screen displays in contrast to tabletop displays outlined in section 3.7.1.

From a formal evaluation of the overall usability and learnability of two final gesture sets Stasche surmises the promise of using gestures as an additional input channel for large display interaction having used an individual laser pointer with gestures. Interestingly, his research provides a first indication of how large high-resolution display interaction can benefit from gestures as an input modality in addition to direct pointing see (figure 3.6); by combining both in a single input device. However, this investigation does not consider multiple forms of input and the effects of such interfaces on group interaction and dynamics (as analyses have recently begun to be considered with regards to tabletop displays e.g. Do-Lenh et al. [2009] discussed in section 3.7.1).

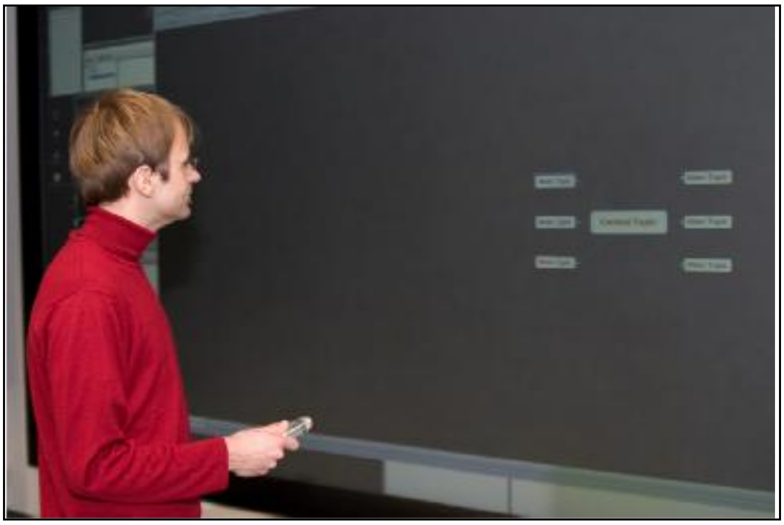


Fig 3.6: Using motion-sensing laser pointer (wireless version) for direct pointing with an electronic mind-mapping application on the POWERWALL large hi-res display [Stasche, 2008].

As a result, Stasche [2008] has initially established the feasibility of gesture usage in the context of a mind-mapping task but does not consider its use in the context of collaboration, following the trend in recent research by Do-Lenh et al. [2009] in the context of table-top interfaces, when using them with large displays. If, as Stasche [2008] contests, gesture based devices are feasible for use with large displays, research in this and similar contexts must therefore consider what happens when gesture based devices are used (multiply) in the context of collaborative concept mapping and the impact they have upon small groups social dynamics, following similar investigations in the use of table-tops by Do-Lenh et al. [2009] and mice and keyboards e.g. Birnholtz et al. [2007].

Crucially, whilst these initial exploratory findings from Stasche intimate the viability of these new modes of interacting in the associative context of mind mapping (as opposed to concept mappings studied here), they are limited to the context of single controller usage and not multiple controller usage which would allow an analysis of the use of these devices in collaborative settings. What is needed therefore is a way through which multiple gesture orientated devices can be used with large-screens to consider their usage and effect on group dynamics when interacting in this way with large-screens.

Research into these areas is important as described by Kurtenbach and Fitzmaurice [2005], who have argued that many traditional user interfaces and interaction techniques have become awkward or next to impossible to operate on large high-resolution displays. These new methods, for use with concept maps, as the focus of this thesis, offer new ways through which to collaborate and work with concept maps and of course other activities. As proposed in Rekimoto [2002] and confirmed by Do-Lenh et al. [2009], group process and performance may depend to a large extent on the availability of entry points and on the forms of interaction. Accordingly, Pawar et al. [2007], multiple mice led to individual learning outcomes comparable to single mouse usage in a memory retention task, with multiple mice solutions preferred by children over a single mouse Stewart et al. [1999]. At the same time, Birnholtz et al. [2007] have found that groups using multi-mice did more parallel work, but ended up with a lower perceived quality of discussion when compared to a one-mouse condition. However, the number of input devices does not affect the equity of physical and verbal participation of group members [Marshall et al. 2008].

3.8 Considering the challenges

Traditionally, a large number of existing concept mapping software are aimed and designed for single users, manipulating concepts through the use of mouse and keyboard through traditional desktop set-ups. Natural interfaces such as gesture-orientated devices for use with large-displays, as well as table-top displays offer new ways of interacting with conceptual knowledge beyond the mouse and keyboard see (3.7.1 and 3.7.2 of this thesis). The main challenges, therefore, with large-displays surrounding their use with concept maps now focus on their use with multiple users (collaboratively) and the subsequent impact they have on the ability of users to work together in small groups, grounded in table-top displays e.g. Do-Lenh et al. [2009], mouse and keyboard usage e.g. Birnholtz et al. [2007] and the potential of multiple gesture orientated research e.g. Stasche [2008]. Enabling users to contribute equally to the process of creating and editing a unified concept map situated in a large-screen environment whilst not impeding group interaction is a challenging task and it is therefore vital to ascertain if and how this occurs in various settings and at the same time not impede the coordination and communication efforts by all users. Previous research e.g. Rogers et al. [2009] has shown how physical actions and types of discussion are indicative of productive collaboration. However, little is known about the relation between physical actions (such as gestures) and aspects of discussion in relation to collaboration e.g. Fleck et al. [2009].

The potential offered by using a gesture and pointing device for use with large displays has been initially explored by Stasche [2008] in terms of its initial viability i.e. in establishing initial gesture sets to use with mind maps. With this initial viability of using pointing and gesturing as a means of input with large–screens established by Stasche [2008] it is therefore important to consider how this mode and configuration of input impacts upon social dynamics when interacting in this way when collaborating with multiple gestures based devices.

Initial exploratory studies, for example, Birnholtz et al. [2007], report that multiple mice allow for more parallel work, but the quality of discussion was higher in the single mouse condition (as opposed to the multiple mouse condition). Moreover, participants were more likely to act in their own best interest in the multiple mouse condition. At the same time Vogt et al. [2004] have observed that groups choose to cooperate differently depending on whether they were using multiple mice or multiple laser pointers, with each device conferring different kinds of advantages for group collaboration. What is important to consider, however, is that 'the collaborative characteristics of input devices are often ignored' and that 'input devices are frequently designed to be used in the context of single user interaction' [Vogt et al. 2004]. Therefore, issuing each user with a gesture-orientated input device, could contribute to the levels of interaction displayed by users when interacting with conceptual knowledge.

3.9 Summary

Researchers have explored various methods for interacting with large displays. However, there does not seem to be any consensus as to which circumstances these different methods are appropriate for, or how these different modalities and configurations affect the user's experiences and the level and type of interaction they display, especially in a collaborative co-located setting when carrying out a conceptual mapping task.

A common approach to interacting with a large display has been through the use of traditional mouse input e.g. Birnholtz et al. [2007]. However newer interfaces such as the Nintendo WiiRemote, and table-top surfaces provide new means through which to combine pointing and gestures, (with greater degrees of freedom of movement than that provided for by Birnholtz et al. [2007]), for use with such environments. At the same time the initial feasibility of these newer modes of input, for use with small groups, have initially been explored by Stasche [2008] and Do-Lenh et al. [2009]. Less traditional methods, performed at a distance, such as that espoused by the WiiRemote, include freehand pointing [Vogel et al. 2005], using laser pointers [Davis et al. 2002, Olsen and Nielsen, 2001, and Vogt et al. 2004], and multi-finger gestural input [Malik et al. 2005]. However, these methods are likely to be less useful for more typical tasks such as creating or editing presentations or documents [see, Birnholtz et al. 2007]. Yet, with Stasche [2008] initially suggesting that the use of gestures with mind-mapping software is feasible, and with the aforementioned techniques typically designed for a single user, it remains unclear as to what techniques are best suited to multiple users of large displays. Especially that form of input which are gesture-orientated and in use by various configurations of user's in small groups.

There have also been some prior studies of groups interacting with a shared smaller display using varying combinations and types of input, largely in the area of Single-Display Groupware (SDG) e.g. Stewart et al. [1999]. At the same time, Birnholtz et al. [2007] provide an initial exploration of single vs. multiple input streams (multiple mice) on group collaboration styles and outcomes when using a large, shared display. However, there has been no systematic study of the impact modality (use vs. non use of pointing with/without gestures) and configuration (multiple controllers) with small groups when collaborating using a large project display in the production of concept maps.

Whilst DiMicco et al. [2004] have studied the impact of a large display on group conversation, they did not focus on input configuration or modalities, whereas Vogt et al. [2004] compared group performance with a mouse versus a laser pointer when completing a maze task, they did not examine the influence on group behaviour beyond speed of reaching a solution. At the same time, where Birnholtz et al. [2007] considered the differences between singular vs. multiple mouse configurations on influence on negotiation, group process and outcomes, they did not consider newer interfaces which allow for greater degrees of movement than when using connected mice e.g. the Nintendo WiiRemote. With Stasche [2008] indicating that a pointing/gesturing device is a viable form of interaction when used with large screens for mind-mapping, it is therefore important to determine how multiple devices, when used in the context of concept mapping affect group dynamics when constructing collaborative co-located concept maps with gestures and multiple controllers. As such, tools have not been evaluated in the context of concept mapping as a means of understanding interaction between students, due to the problems of creating and designing Graphical User Interfaces for multiple cursors, e.g. Tse and Greenberg [2004], let alone other devices not commonly supported by operating systems such as the WiiRemote. This is despite the promises that these devices offer for interacting with conceptual knowledge e.g. Milne [2007].

At the same time, with the recent development of tabletop surfaces, people, when interacting in small groups of people around them, are offered new possibilities through which to interact and collaborate beyond the use of mice and keyboard. The potential of tabletops allows groups of people to manipulate a shared display simultaneously and provide the context for exploring how small groups interact when using these devices. For example, Fleck et al. [2009] have revealed that what might be considered undesirable or harmful interactions and intrusions in general collaborative settings might indeed be beneficial for collaborative learning. Yet little is known about the type of interactions that occur in these settings or how they affect group dynamics. Previous research has suggested that this technology is enjoyable to use, promotes playfulness and can lead to learning e.g. Do-Lenh et al. [2009], Harris et al. [2009], Piper et al. [2009] and Rogers et al. [2009]. However, recent studies on collaboration around tabletops have shown the effects to be small or insignificant when compared with other technologies e.g. Harris et al. [2009], and also in the realm of concept mapping e.g. Do-Lenh et al. [2009].

There have been several studies concerning the impact of tabletop usage and its subsequent impact on group process and performance. Initially, Ryall et al. [2004] reported on the effects of group size and table size on task performance. Rogers and Lindley [2004] have also shown that small groups were more comfortable working around an interactive tabletop than in front of a pc or a vertical display. At the same time Rogers et al. [2009] found that group process and performance may depend to a large extent on the modes of interaction. Such findings are useful when considering more recent development in creating interfaces for concept mapping e.g. Do-Lenh et al. [2009] who used a tabletop system that enabled students to interact via paper pieces as well as using direct touch and compared the system’s ability to support students’ performance to the traditional computer system. At the same time Stasche [2008] has recently formulated a gesture set for use with large-screens when mind-mapping. With this trend towards developing new interfaces for concept mapping in a collaborative context for table-tops the possibility of extending collaboration with large screens and tangible devices exists when interacting with concept maps (with a method for doing so outlined in chapter 4). With group dynamics effected by freedom of movement during experimentation e.g. Marshall et al. [2008] and Do-Lenh et al. [2009], the impact of collaboratively using tangible devices in this way must also be considered.

4. Software design and implementation

4.1 Introduction

It has been identified in Chapter 3 that there was no software support for the multiple use of gesture-orientated input devices with concept mapping software in co-located environments. Traditionally, GUIs are generally designed for use with single users and therefore do not support multiple devices, with independently controlled pointers. Furthermore, traditional concept mapping perpetuates this model, with the vast majority of concept mapping situated around individual users using a mouse and keyboard configuration, where collaboration occurs through file repositories of shareable concept maps. With the introduction of more natural interfaces and the pervasiveness of large-screen projectors the established ideas of collaborating with concept maps can be redefined. However, to do so, the tools required to achieve this transformation need to be constructed.

Initially this chapter highlights the processes through which the concept mapping software was developed before considering the challenges presented by the requirement to create multiple and gesture-orientated co-located collaborative concept mapping. It also presents the WiiConcept approach and the software components which constitute its creation. The focus therefore of this chapter is the discussion surrounding the multiple controller based input, and also the processes involved in the development of the conceptual mapping software. The discussion then changes focus to discuss how WiiConcept synthesises these two areas and as a result defines its technical contribution to this area. Having determined the area for this discussion the architecture and design for the system will then be presented, before detailing the means of interacting with the software, which allows the systems users to collaborate with concept maps using gestures.

4.2 Software requirements

Chapter 3 highlighted that knowledge construction and visualisation techniques to support learning are not as prevalent in Higher Education in the UK as research promoting their benefit suggests they might be e.g. Kinchin, [2001]. At the same time motivation to use them is low and, in their present form they are not always received positively by students or their teachers [Santhanam et al. 1998]. Additionally, even students that volunteered to use them were not all eventually in favour of their use e.g. Barenholz and Tamir [1992]. More natural user interfaces presented in Chapter 3 provide the promise of increased interaction and engagement and, when considered in the context of large-wall sized screens, offer new ways of interacting with conceptual knowledge. A number of interaction techniques have been investigated for large displays 'including natural gestures, voice recognition, multi-handed interaction techniques, and methods to improve the reach of the user' [Ni et al.2006]. These techniques showed promise, but 'need to be evaluated for specific tasks in order to gain a better understanding of how effective they are for interacting with large displays' [Ni et al. 2006], especially in terms of how they can facilitate and aid in the construction of knowledge by engaging and encouraging interaction with students.

With minimal software support for the multiple use of gesture-orientated input devices with concept mapping software GUIs in co-located environments, as (identified in Chapter 3) the principal requirements of the software surrounded the need to incorporate this gesturally-orientated interaction (when attempting to understand its usage in a collaborative context) for the specific conceptual-orientated task undertaken here when used with large, wall-sized screen usage. As the underlying theme of this investigation is collaborative in nature, then multiple controllers need to be added to the system. At the same time, the system to be developed is a concept mapping system and therefore needs to allow students to create concept map diagrams and must therefore support the functionality that allows concept maps to be created.

The main features incorporated into the system therefore concentrated on providing a simple concept mapping tool which provided for the use of multiple controllers with gestures. These features allowed:

1. for the use of gestures with multiple controllers to manipulate conceptual nodes, delete nodes, zoom in and out, connect conceptual nodes and open new concept maps;

2. for the multiple use of controllers with infra-red based pointing for improved control and sensitivity;

3. textual input for both conceptual nodes and links through the use of predictive-text based input;

4. the loading and saving of gestures and;

5. colour coded representation of concepts by user number.

The above features, (1 to 5 listed above) were identified for the following reasons:

a) Infra-red based pointing was required for multiple controllers as other methods such as using the up down arrows on the WiiRemote would result in jagged movements which would inhibit the construction of the concept maps from a usability perspective. This would be due to the user having to make a series of movements to move up, then across, then up then across if they were trying to move to another section of a map. Infra-red pointing on the other hand negates this issue, in allowing the cursor to move in the same way as a 'normal' mouse, where one fluid movement would allow the same process to be completed.

b) Predictive-text based input was used as it allowed the creation of smaller text-pads through which to input text into the system. As the concept mapping software required the multiple use of textual-forms of input, the predictive text element would significantly reduce the need for large text-pads that were dependent on individual buttons that represented the letters of the alphabet. As a result, multiple letters could be assigned to one key on a text-pad and reduce dramatically the focus from the key-pad back to the concept map.

c) The loading and saving of gestures was also required as there was no function through which to do this in the Wiigee library [Schlomer et al 2008]. To ensure that the gesture sets across all conditions were the same, and that any subsequent variations across experimental conditions were limited to the factors under study, the ability to save the master gesture set and load this was crucial. Otherwise the gestures would have to be recorded before each experiment, with variation as the gestures were re-entered for each experiment. Different groups, without this feature, would then have experienced different levels of recognition rates.

d) Finally, the colour coding of the nodes and pointers that constituted the concept map was also introduced to ensure that when users were using two-controllers they were able to ascertain, which cursor was theirs and also what it was they had created. This was engineered to prevent the users becoming confused when interacting with the concept maps.

This feature set also met the principal requirement of ensuring that the experiments could be undertaken allowing four software conditions (see section 5.2.1 for a detailed guide as to the experimental design) which were:

1. Software that did not enable gestures with one-controller;

2. Software that enabled gestures with one-controller;

3. Software that did not enable gestures with two-controllers;

4. Software that enabled gestures with two-controllers.

With these experimental conditions established, an assessment of controller configuration and mode of input on levels and type of interaction when constructing concept maps could then be considered (see Chapter 6 of this thesis for the results of these findings).

4.3 Concept mapping software

This section discusses the processes involved in the selection of the conceptual mapping software through which the features outlined in section 4.2 of this chapter were to be incorporated. It also outlines the justification for choosing the software as well as briefly presenting the selected software's features.

4.3.1 Process and justification of software selection

There are some 350+ concept mapping, mind-mapping, activity maps, diagramming, and idea support software tools [Software for mind-mapping and Information Organisation, 2010], with some forty eight entries for concept mapping tools alone. The process of selecting a concept mapping system through which to build the additional features required by this research from the vast number of available software packages might therefore be considered difficult. However, a large number of these systems could be discounted for use as they were commercial in their development and as a result not open-source and therefore could not be developed. Further systems were discounted as they were web-based, or designed to be used when users were not co-located.

Possible concept mapping systems were further discounted as they were not developed for use with Java as a development environment. (For a discussion of the reasoning behind using Java as a development environment please see section 4.5.1 of this Chapter).

A further requirement of the potential concept mapping software was that it also needed to be extensible and adaptable, without overly complex features as the process of concept mapping would be under study rather than the complexity of it. Therefore, the concept mapping software needed to be relatively simple with only the functions necessary through which to concept map.

The software that was selected was Violet_uml version 0.1 which is a UML diagramming tool rather than a specific concept mapping tool. This tool was selected based on the criteria outlined above. Crucially, it was one of the very few tools that was open-source and developed in Java (for later use with WiiRemote based APIs). Furthermore, the UML diagram components that were present in the software could easily be updated to provide the additional features required by the WiiConcept software.

4.3.2 Violet_uml

Violet_uml version 0.1 implemented the following features:

- can open multiple documents;
- supports direct links between UML diagrams;
- save/load concept map;
- single mouse support;
- automatic grid snap and;
- zoom in / zoom out.

With the ability to create use-case diagrams, and class diagrams etc. the software contained the essential components through which to develop a non complex concept mapping tool quickly and effectively, which could then incorporate the new multiple controller and gestural input, as well as the predictive text input capability for entering information into nodes and links as well as for editing them. However, one feature this software did not offer was the ability when snapping a relationship between nodes to automatically create a text box for text entry of that node's relationship to another node.

This feature was therefore added, in conjunction with the predictive text input systems. This was because the initial Violet_uml software required that a note node was created which was separate and independent to the relationship. This was not suitable for a concept mapping system as when the user wanted to move a node, or series of nodes the relationship node would not move with the moved conceptual node as it was not part of the initial relationship. Therefore, if the user had twenty nodes, with twenty relationships, that had twenty associative relationship text boxes, the user would subsequently have to move a proportional amount of relationship text boxes to the amount of nodes moved to maintain the diagram's cognitive structure. Such a scenario, due to the aforementioned addition was therefore negated.

At the same time, the predictive text system was implemented as the text system associated with the system was reliant upon mouse-based input, whereby the text input was input via a keyboard. Predictive text, in contrast, meant that the potential user of the system could click fewer buttons when pointing with the device, which would hopefully therefore reduce arm fatigue. Furthermore, the user, in using predictive text, would not have to be limited through movement by using keyboard based input when interacting with large displays.

4.4 Multiple controller input

The traditional design of computers restricts the amount of collaborative interaction due to the limits of the use of a single cursor or input device (e.g. mouse or keyboard) per machine, limiting the types of collaborative activities that computers can be used for. While evidence suggests that collaboratively creating concept maps may have benefits for learning and understanding, technology needs to develop beyond the single-user norm, to allow for multiple input devices. One direction is an application that supports a group of people around a single display, by enabling input by each individual, known as *Single Display Groupware* (SDG) [Stewart et al. 1999]. Early efforts to implement multiple input devices include Bier's MMM [1991] and Hourcade's MID [1999].

Initially, it is relatively easy to plug in more mice or connect multiple controllers by simply adding more mice into available ports or connecting multiple controllers. However, in this situation, all of the mice or controllers actions would be associated with the same cursor, with the sum of the mouse/controller motions being used to control it. To overcome this problem in the context of mice, Tse and Greenberg [2004] have written a well-designed toolkit (the SDG Toolkit) for prototyping SDG applications. Using this API, the RawInput data and calls associated with a mouse are packaged in a .NET-compatible event manager, which supports the use of multiple mice. This toolkit then allows developers to modify these mouse-events and thus allows for the drawing of separate customisable cursors on screen, by creating transparency-enabled movable windows per cursor.

In using such a toolkit, however, the user is limited to input which is mouse and keyboard driven; this is inconvenient when collaborating with large-screen displays. Additionally, there is no support for gestural interaction to aid in the movement towards more playful and engaging modes afforded by the WiiRemote.

4.4.1 Technical contribution

To enable the type of collaboration that we envision, the system would require support for multiple controllers, for both pointing and gesturing. To provide this combined input the WiiConcept software would have to overcome the principal challenge of incorporating multiple WiiRemotes in the same way as those presented by multiple mice e.g. multiple identification of input (with the additional complexity of gestures), multiple cursors (one for each attached controller) as well as user controllers (which are not designed to handle concurrent use).

Having multiple users working together around a shared display is fundamentally different than having a single user work alone. Many interface elements, such as menu bars and toolbars, that are effective for single user applications, must be re-evaluated for this new interaction paradigm. This re-evaluation is necessary so that the benefits provided by this style of collaboration can be fully realized and optimised for their use with concept maps, outside of the context of multi-user touch displays e.g. Higgins et al. [2009]. The software attempts to address the need for more engaging interaction techniques with conceptual mapping software, by incorporating gaming interfaces like the Nintendo WiiRemote, which provides options for creating gesture-based input commands beyond the move-click capability of a mouse, when interacting with large screens and concept maps.

As such a WiiRemote environment needs to be incorporated into a concept mapping tool that provides the potential for graphical interaction beyond that of conventional controls such as buttons and menus and it is here that gesture-orientated devices offer further advantages in that these traditional modes of interacting with GUIs can be ignored via the introduction of gestures. However, the recognition of these gestures and the functionality afforded by these controllers when used as mice must be incorporated into the system. Graphical user interfaces and the support offered for them have in the past been focussed on this single user environment. The challenge, therefore, is to incorporate new interaction devices but also, at the same time, provide integration and support for multiple users of these devices. This is the principal aim of the WiiConcept software; namely to bring together and adapt these devices into conceptual mapping based software. As such, the principal technical contribution of WiiConcept is in its merging of conceptually based software and integrating its use with multiple IR-based pointer and gestural devices.

The over-riding principal problem that needed to be overcome was the issue of multiple controllers and their subsequent use with graphical user interfaces i.e. multiple cursors discussed initially in the context of Tse and Greenberg [2004]. The approach used to solve this issue was provided by the GlassPane class used in Java development. Overlaying the frames of the software at the highest level within Java applications is a GlassPane. To enable there to be multiple controller pointers on the screen the pointers (that is when the IR data had been converted to x, y positional data) could be drawn on top of this GlassPane, with the mouse capability overridden so that it would be updated from the accelerometer data rather than through mouse events.

Mouse capability could then be cloned to the controllers through the button input associated with the controllers and routed through the main WiiConcept editor frame. However, one further problem that this solution presented was that if a new frame was opened within the main editor frame e.g. the predictive text input frame, then that frame would essentially be the active frame, which would itself have a GlassPane. This meant that effectively the GlassPane associated with the main frame would have control of the pointer, when, obviously, the text input frame would require priority. To overcome this, additional frames for users 1 and 2 could be used which would act as the GlassPane in relation to the predictive text frame. With the GlassPane of the predictive text frame in priority the pointer associated with the main editing frame would therefore have to be switched off, but only for the specific user, so that there would not be multiple cursors for one user at different hierarchical levels of the program.

4.5 WiiConcept

4.5.1 Java and Bluetooth

To achieve this synthesis between conceptual mapping software and the WiiRemotes, various development APIs were considered. Most APIs focused on providing the connection of the device, and did not incorporate support for gesture recognition and as gestures were required for the development of the system, an API was required that also incorporated gesture support.

An API that supported the use of gestures with WiiRemotes was the Wiigee API developed by Schlomer et al. [2008]. However, the Wiigee library, through its gesture-orientated nature lacked integration with singular or multiple mouse-based input. As the software required the ability to point and gesture, adaptations had to be made whereby WiiConcept became a hybrid of the WiiRemoteJ library for the initial connection and setting up of controllers, as well as the Wiigee library for the use of the gesture recognition capability. WiiRemoteJ, however, only provided infra-red based mouse support for one-controller for one-controller cursor. Therefore, the software capability of WiiConcept was extended to include multiple IR-based mouse functionality, rather than the singular capability that was built into WiiRemoteJ and resulted in the IRToMouse and IRToMouseListener classes (see section 4.5.3.1 of this Chapter).

With the gesture-based functionality grounded in Wiigee (which was coded in Java) the environment was therefore coded in Java, with WiiRemoteJ used to provide the initial controller connection support and additional functionality. To provide the WiiRemote connectivity a Java JSR-82 implementation was required. The JSR-82 implementation provides Bluetooth functionalities to Java software in a standardised way and, therefore, by incorporating it within the software you can offer Bluetooth services, search for remote devices or connect to remote devices' services by using a well documented Java interface (JSR-82). Therefore, to communicate and interact with the controllers, which rely on Bluetooth Communication, a JSR-82 implementation was required. Because, WiiRemoteJ requires a Windows environment the supported WIDDCOMM stack was used, with the BlueCove Bluetooth JSR-82 implementation. There are many other implementations available i.e. Avetana Bluetooth, however, BlueCove was chosen as it did not require a fee to use and supported the stack available. It had also been tested in the context of WiiRemoteJ and was therefore well supported.

4.5.2 System structure

The system structure is a way of viewing the subsystems and modules which constitute the system and also aids in the understanding of how these systems and modules interoperate.

Figure 4.1 shows a high level view of the WiiConcept system and the communication process between the initial WiiRemote Event and the WiiConcept software. Initially an event triggered by the WiiRemote (the event source) is sent by the user to the system via the Bluetooth stack, which interfaces with WiiConcept (in tandem with the WiiRemote libraries) to allow the user to manipulate the WiiConcept software. Therefore the WiiConcept software is reliant upon the WiiRemoteJ API for the initial connection of the controller(s), with the Wiigee API providing the components through which the system listens for and interacts with gesture-orientated events. As such, the WiiConcept software integrates these WiiRemote libraries to provide the controller connectivity and gesture capability by listening for events from the controllers allowing for the manipulation of the WiiConcept mapping software.

Having outlined the communication processes and the high level system structure it is important to consider the components which constitute the WiiConcept system as well as their design.

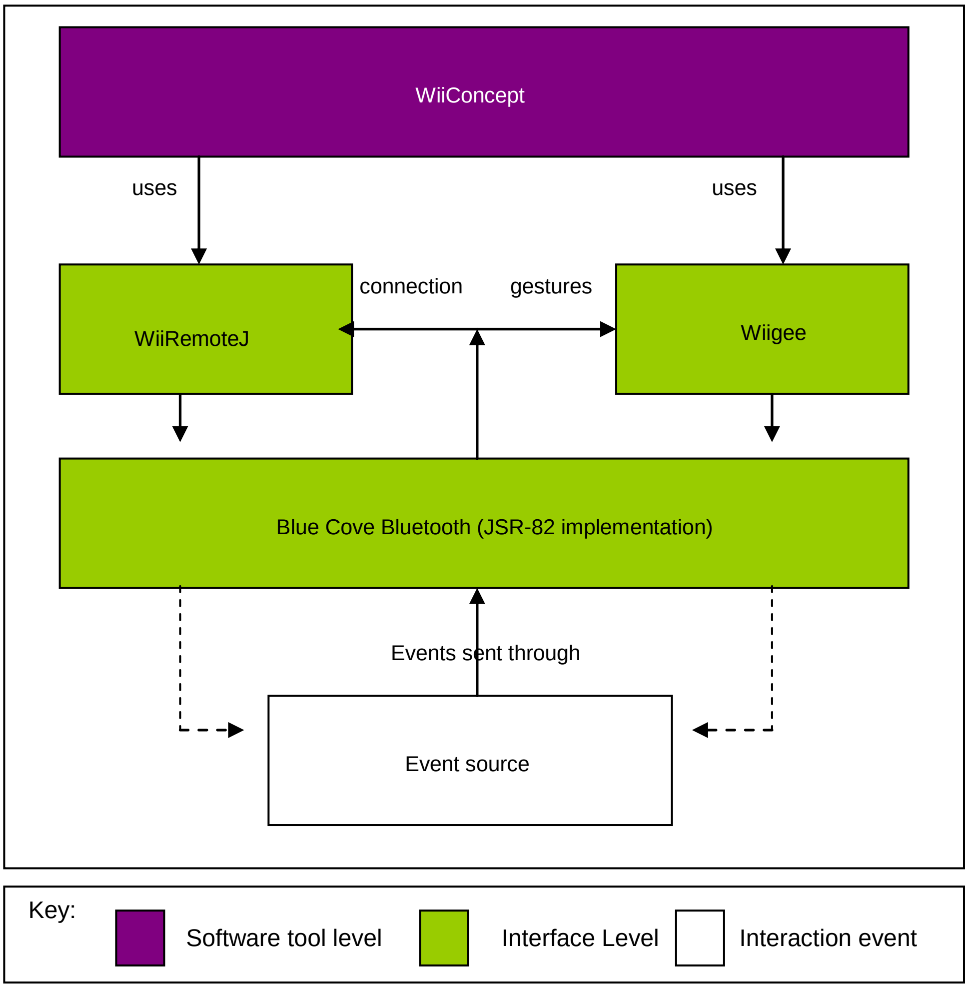


Fig: 4.1: WiiConcept communication system overview.

4.5.3 Software component design

The components that constitute the WiiConcept software are summarised in Figure 4.2 and include the additional user functionality summarised in section 4.3. (Components that are coloured blue in Figure 4.2 signify modified code and boxes that are highlighted red show new code with green boxes indicating package components which contain modified and new code).

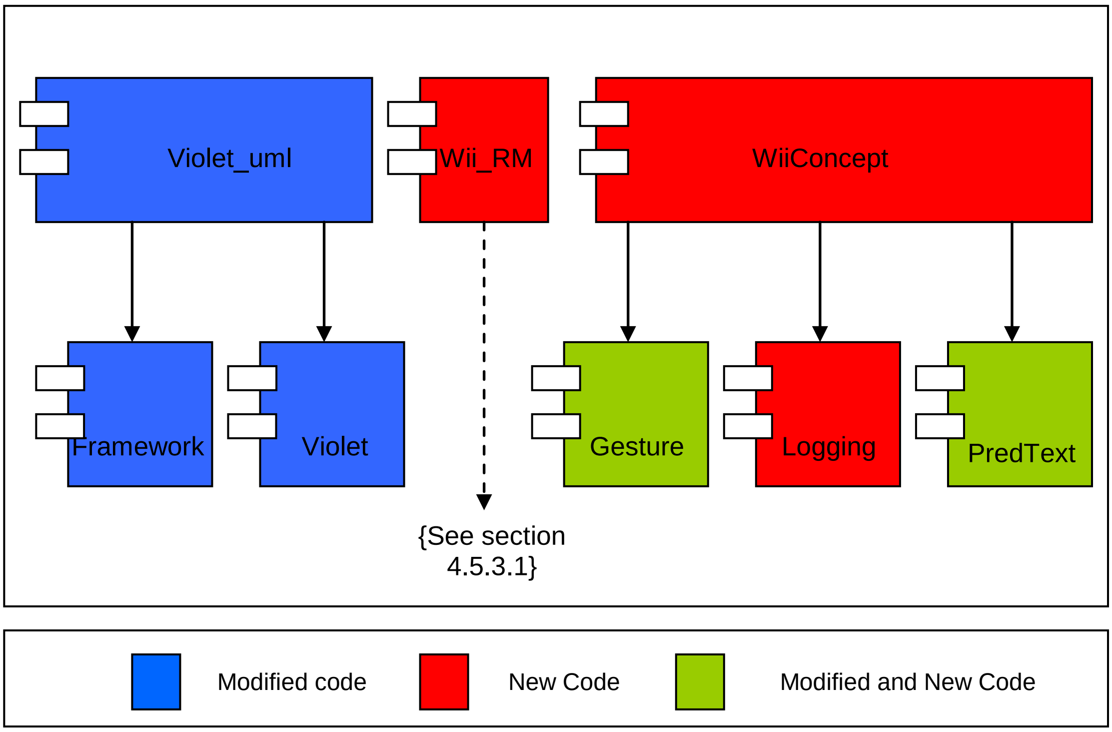


Fig: 4.2: WiiConcept high-level component design.

The principal components are the re-used source code from Violet_uml, as described in section 4.4 of this Chapter, and its subsequent integration with WII_RM (which handles the set-up and management of the WiiRemotes) and WiiConcept (which includes modified code through which new functionality, including gestures and predictive text, are added to the system).

It is worth noting at this point that the Violet_uml component will not be discussed as the source code for this component is freely available see [Violet_uml, 2010]. Where modifications have occurred in this package they concern the structure of the software and the layout of the frames which form the editor software. Extensive work was also, therefore, required in modifying the text input system to ensure compatibility between the new predictive system and the existing mechanisms in Violet_uml that were reliant upon keyboard input.

Additionally, and to improve usability, note nodes have been added so that they are included as part of the relationship between nodes, which did not exist previously. All changes in this component ensure that the remaining packages are run and incorporated within the software framework as a whole and it is here that the GUI is changed so that the software responds to gesture- based input.

This section will now continue to outline some of the more interesting system components shown in Figure 4.2 in sections 4.5.3.1. and 4.5.3.2 of this chapter.

4.5.3.1 Design of the Wii_RM component

The Wii_RM component contains all of the classes through which to connect the controllers and manage their multiple use with their specific classes. This component fulfils one of the main objectives of the concept mapping software in that it allows for the management and connection of multiple IR WiiRemotes to the system, which are fully integrated with the gesture capability associated with the WiiConcept gesture component. The principal idea of this component is to allow users to connect multiple controllers, as well as disconnecting them with the additional functionality of precise IR driven mice.

Figure 4.3 shows the Wii_RM component in detail, and also its relation to the WiiConcept, WiiRemoteJ and Violet_uml components. The red implementation arrows in Figure 4.5 signify the use of these classes of the associated listeners. For example, the EditorFrame implements the IRToMouse Listener as the EditorFrame (in the Violet_uml software) is responsible for where the conceptual diagrams are edited and therefore needs to listen to IRToMouse Events. The classes which are of particular interest are the GraphGlassPane and PredTextGP1 and 2 classes.

Overlaying the frames of the software at the highest level within Java applications is a GlassPane. To enable there to be multiple controller pointers on the screen the pointers, (that is when the IR data had been converted to x,

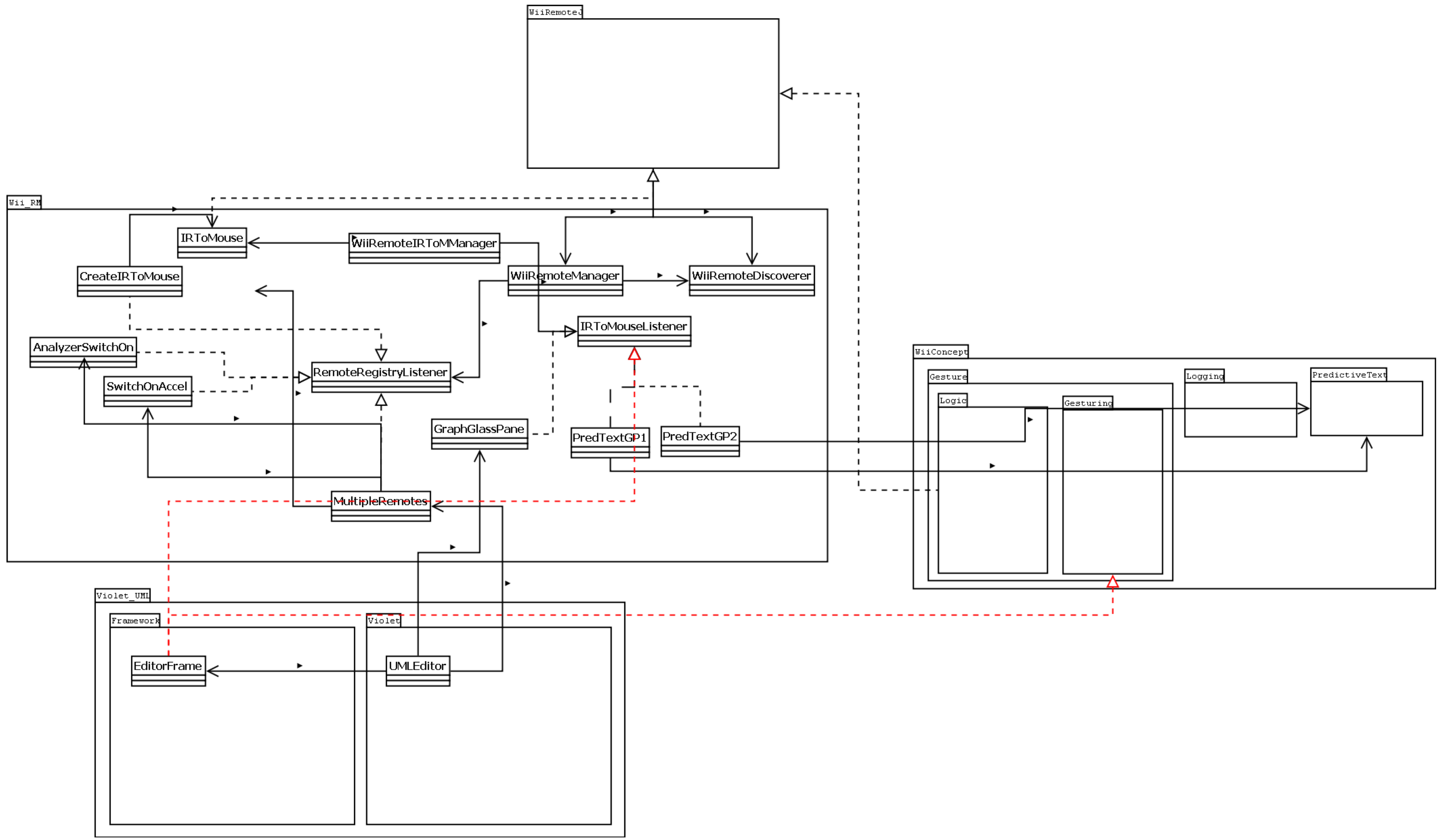


Figure 4.3: Overview diagram of the inter-relation of classes which constitute the Wii_RM component

y positional data) could be drawn on top of this GlassPane, with the mouse capability overridden so that it would be updated from the accelerometer data rather than through mouse events.

Mouse capability could then be cloned to the controllers through the button input associated with the controllers and routed through the main WiiConcept editor frame. However, one further problem that this solution presented was that if a new frame was opened within the main editor frame e.g. the predictive text frame would essentially be the active frame, which would itself have a GlassPane. This meant that effectively the GlassPane associated with the main frame would have control of the pointer, when obviously the text input frame would require priority. To overcome this PredTextGP1 and 2 were used for user's 1 and 2 which would act as the GlassPane in relation to the predictive text frame. With the GlassPane of the predictive text frame in priority the pointer associated with the main editing frame would therefore have to be switched off, but only for the specific user.

4.5.3.2 Design of the WiiConcept component

The WiiConcept component is concerned with the incorporation of the gesture capability and additional functionality of the predictive text component. Essentially, all of the new functionality associated with the Violet_uml component is contained in this component. It is separated from the Violet_uml component so that it can easily be maintained, updated and, if necessary, removed. Therefore, the principal subsystems of this component are concerned with the gesture capabilities i.e. the gesture logic (provided for by Wiigee) and additional gesture loading/saving support, and the predictive text functionality.

Figure 4.4 summarises the gesture components within the additional functionality of the WiiConcept Package. The gesturing component contains the associative GestureListener which is used by classes that are interested in listening for gestures. The Acceleration StreamAnalyzer class has at this point been activated when the controller connects through the Wii_RM component, and loads the gestures which have been previously saved, when the initial training session was completed. This new and additional loading/saving functionality is included in Fig 4.4.

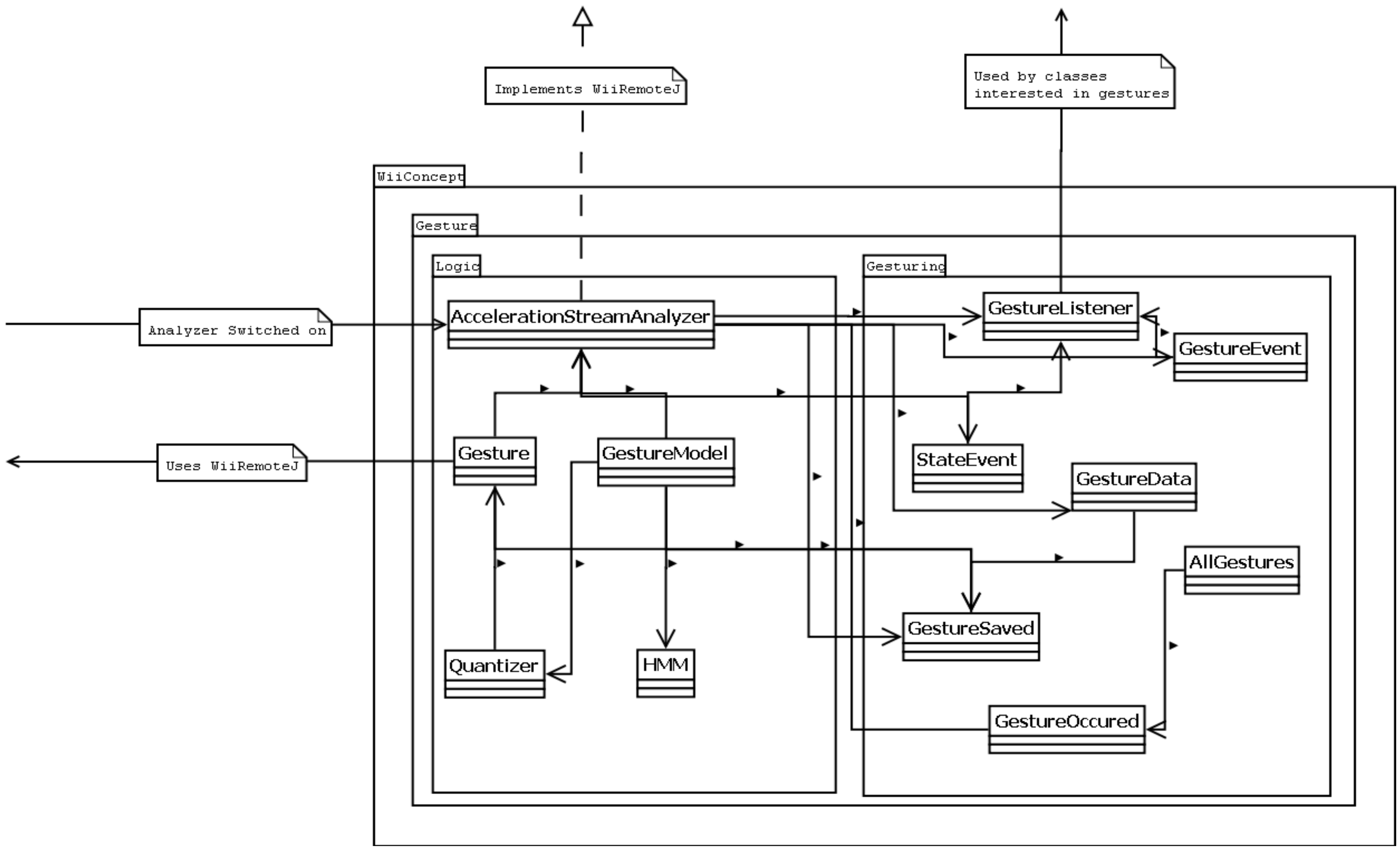


Figure 4.4: Class diagram of the gesture-orientated component of the WiiConcept package.

4.5.4 Interaction design

4.5.4.1 User views

Figure 4.5 is a screen shot of the user's view of a completed concept map used in the experiments when using two-controllers without gestures. Note that the interface is simple and clean in design as to not influence or over complicate the user's later interactions with the interface in the experiments. The display itself consists of a toolbar containing the controls for user one (indicated by the blue buttons on the interface) and user two (as indicated by the red buttons on the interface).

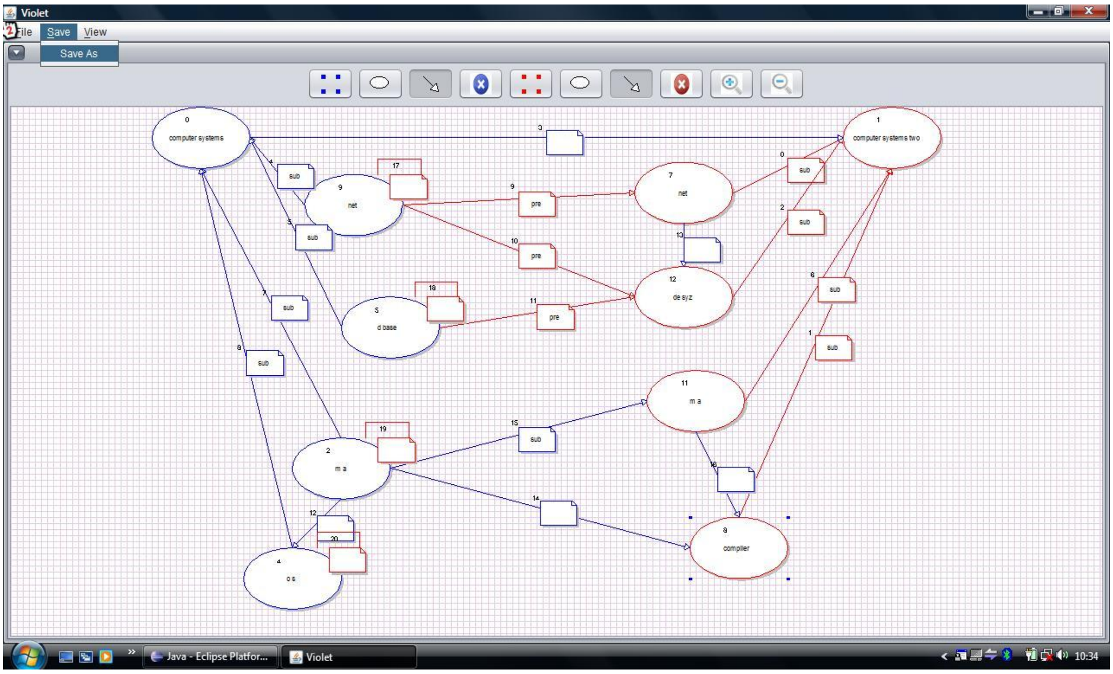


Figure 4.5: Screen shot of user's concept map when using two-controllers without gestures enabled.

Beneath the toolbar the main concept mapping area is located where both users can create nodes, link them and delete them. Negotiation is required for the purposes of zooming in and zooming out (this is signified by the set of magnifying icons located in the toolbar). Users within this concept mapping environment maintain control of their own pointer and can add concepts, links and words via the controllers. Figure 4.5 also shows who created the nodes and links by colours (blue for user one and red for user two) and the entering of words into nodes is tracked via the log files.

Figure 4.6 indicates the visual layout for the use of the system with two-controllers with gestures enabled. The tool bar contains the selection and arrow drawing options, but all other options are replaced with the use of gestures.

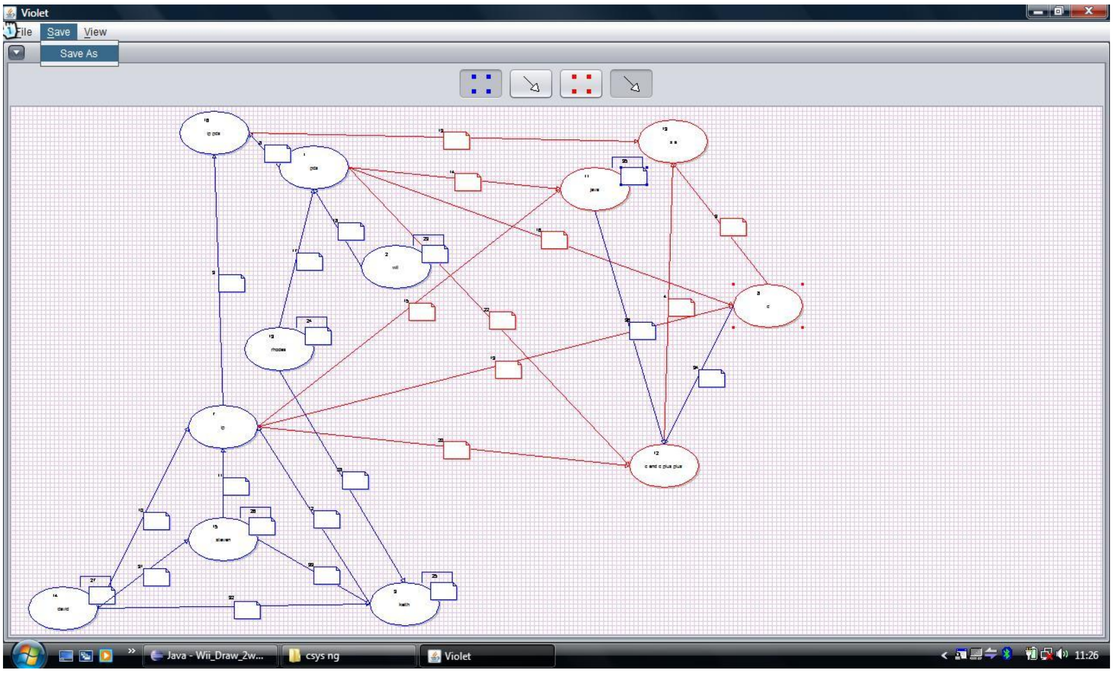


Figure 4.6: Screen shot of user's concept map when using two-controllers with gestures enabled.

The visual layout described above and summarised in Figures 4.5 and 4.6 are also representative of the one-controller set-up. However as there is only ever one user in possession of the controller there is only ever one set of icons in the toolbar and not two.

4.5.4.2 User controls

The user controls are summarised in Figure 4.7. The controls are designed to replicate the configuration of buttons used when interacting with a Wii when using a WiiRemote. Therefore, the trigger button simulates a mouse press and is used for the grabbing of objects within the WiiConcept system.

Button A (Fig 4.7) was assigned to do all of the editing in the software and, therefore, acted like a right button click on a mouse. This method was also used due to an implementation issue caused when in a process mode, i.e. whether the controller was in selection or line drawing mode meant that in double selecting a concept node a user may have subsequently moved the node if they thought they were in selection mode by pressing the trigger button. Therefore, a separation of function would eliminate any confusion in processes by having a separate button.

The + button was used to select letters when inputting text into the system. This was because any input with the trigger buttons on these buttons would be listened to by the frame beneath and therefore had to be deactivated in the

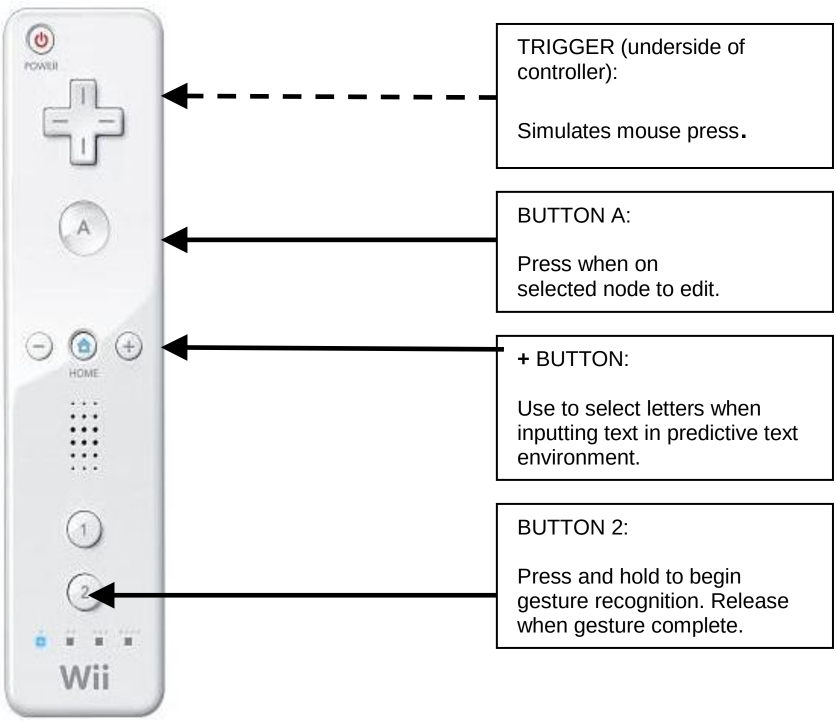


Fig 4.7: WiiConcept system controls.

text input frames. Failure to do this would, if this button mapping was not introduced, mean that a user would mouse click on the textual input node and a conceptual node would be created in the frame below the top frame of the textual input. With regards to the subsequent use of this configuration, all groups had the same amount of time to practice these controls before the experiment began.

Button 2 would be pressed to start the recognition process and released when the gesture recognition process was completed.

4.5.4.3 User gestures

During *training* the experimenter recorded the gestures the application later taken as input commands. These are summarised in Figure 4.8.

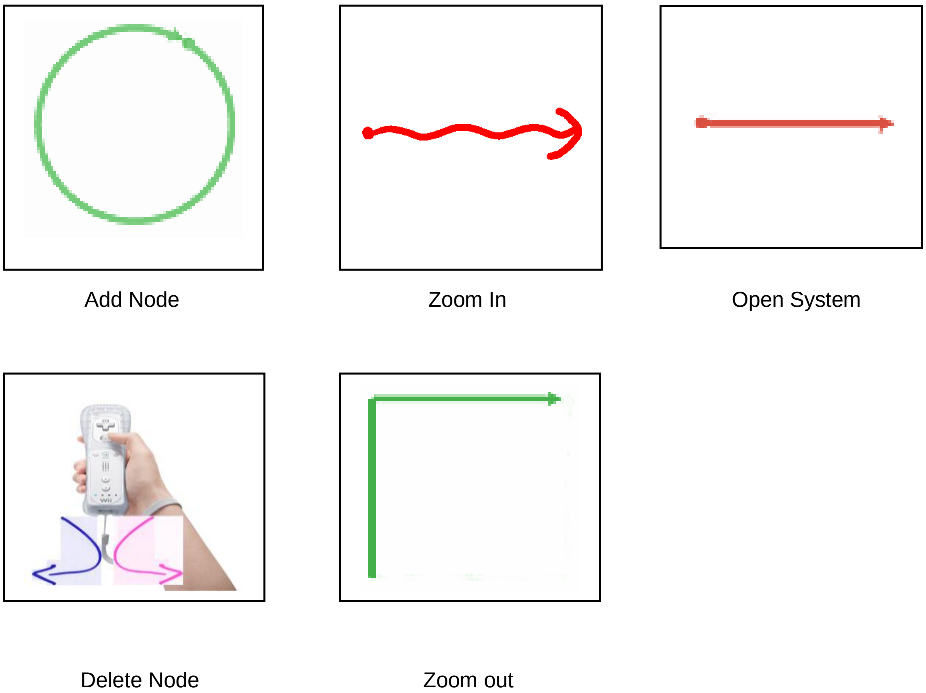


Fig 4.8: WiiConcept system gestures

The training of the gestures is a recording process triggered by a specific *TrainButton*. This *TrainButton* must be held down during recording. Releasing it marks the end of the recording process. Repeating this whole procedure further trains the system and, by that, makes it more likely that a gesture is correctly identified during the later phase of recognition. Schlomer et al. [2008] found that five to ten training sessions are a necessary minimum to get feasible results but recommend ten to fifteen. For this purpose, each intended gesture was performed twenty five times both left and right handed and using various configurations of the proposed gestures. This, therefore, allowed the system to learn the gesture and internally generate a code for it. (For comments evaluating this recognition and training procedure used here please also see Chapter 6 of this thesis).

During *recognition* the software, through the incorporation of the Wiigee API, attempts to identify the gesture which has just occurred by computing which of the trained gestures fits the performed one (due to the probability that the user was performing that gesture) and then based on this event carries out the associated action to the gesture. To incorporate multiple controllers this system had to be extensively modified to enable the recognition of gestures as distinct from each controller. This recognition process is highlighted in Figure 4.9.

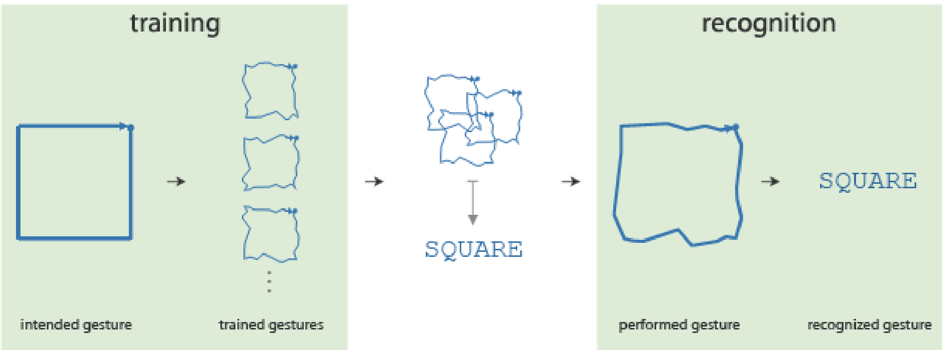


Fig 4.9: Gesture training and recognition process.

Additionally, and to avoid any bias in gesture sets the same gesture set was used for each of the experimental conditions; so each controller used the same trained gestures. When the user wishes to complete a gesture they press Button 2 on the controller to perform the gesture and then released it (see Figure 4.7) to end this process. Additionally, the Wiigee API did not provide its own methods to store training data into a file or to load such stored data, nor did it do so for multiple controllers. These features were therefore added.

When considering the gesture set used here (see Figure 4.8) Stasche [2008] provides an exploratory investigation as to the suitability of various gesture sets with a mind mapping tool and large screens. The gesture set presented by Stasche [2008] have been adopted in this experiment, although due to the smaller number of functions the gesture set used here is reduced in number to core concept mapping activities to minimise the amount of gestures users were required to learn and any subsequent impact this may have had on cognitive load.

4.5.4.4 User text input

Having explained the incorporation of the multiple controllers and the gestures into the WiiConcept system the reasoning behind the predictive text input and its set-up will now be considered. Figure 4.10 highlights one of the predictive text inputs being used.

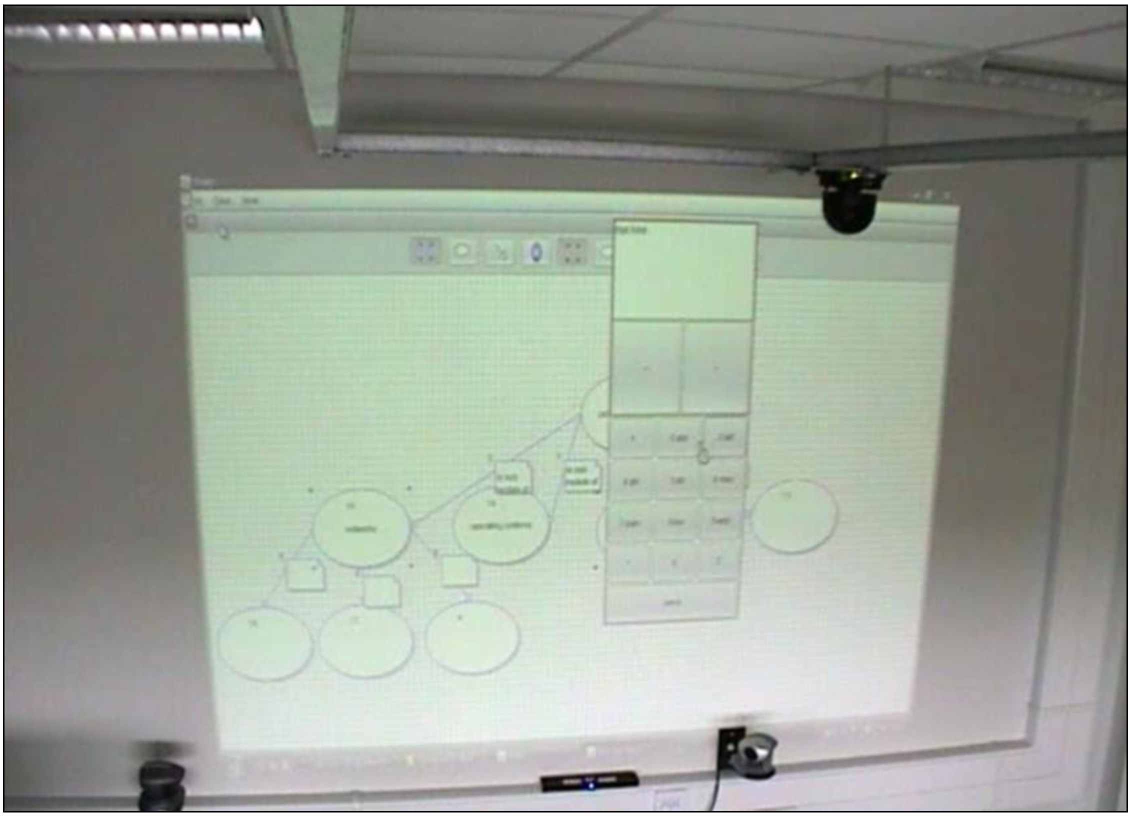


Fig 4.10: The predictive text functionality when used by experimental participants.

Two of these predictive text-boxes can be open at any one time allowing the users to input data into different nodes or edges at the same time. However, each person is only allowed to type in their own predictive text box, with each box again colour coded to match their cursor control. Due to the limitations of the approach to allowing multiple cursors, as described in section 4.3.1 of this chapter, the user cannot select the predictive text box when the cursor is active within the selected JFrame which overlays it. This is because the edges which surround the frame are outside of the range of the GlassPane listener when the controller is active in the JFrame one level down.

The predictive text functionality is described in Figure 4.11. Predictive text was used as it was designed to reduce the amount of times the user had to click on the buttons at distance from the screen as it was anticipated that to do so would be difficult, due to the limitations of the WiiRemote as a pointing device i.e. sensitivity issues. These usability issues are discussed in the evaluatory chapter of this thesis (see Chapter 7).

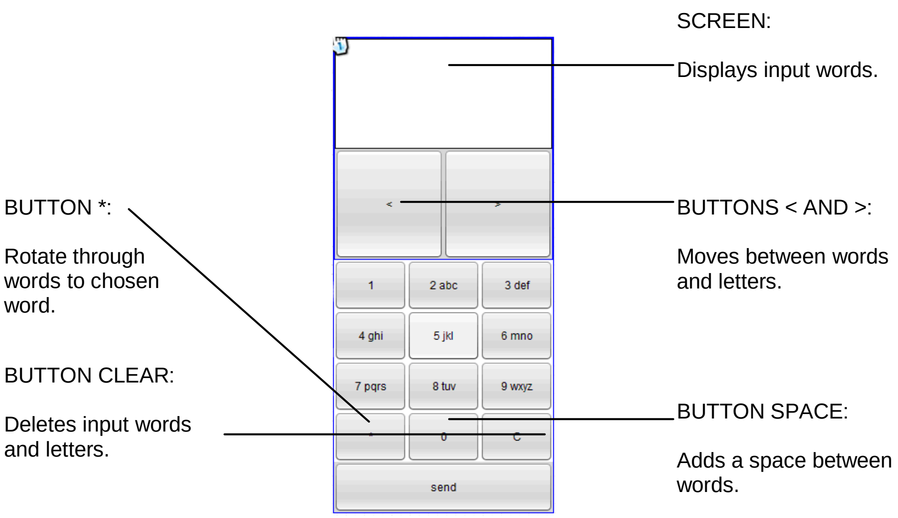


Fig 4.11: The predictive text key-pad layout.

4.6 Summary

The aim of developing this software was to allow multiple users (but in this case limited to two) the ability to maintain control of their own pointer using the more responsive IR-based pointing capability, whilst also using gestures, to construct and manipulate concept maps. To meet these objectives the proposed solution combined elements of existing mapping technology and incorporated aspects of WiiRemote and Wiigee-based gesture recognition APIs into the resultant WiiConcept system. These APIs were modified to include support for multiple controllers and gestures in the context of concept mapping and their use with predictive text input.

Additional functionality was implemented e.g. the loading and saving of gestures to allow the proposed experiment (see Chapter 5) to be completed. Rapid prototyping with users was used as the software design principal, with the end result providing the necessary software through which to test the experimental hypotheses with extraneous features therefore not included within the system. To counterbalance this rapid prototyping, additional features were identified that would constitute future work and are therefore discussed in Chapter 7 of this thesis.

The solution proposed to the problem of allowing independent control of two mouse pointers incorporated the use of GlassPanes and the conversion of IR data to multiple cursor points in this context. The use of gestures was based on existing research and the recognition of these gestures was explored in the context of previous usage of this API for recognition purposes [Schlomer, 2008]. Predictive text was also used as a means of text input into conceptual nodes and relationships between nodes.

Having constructed the software presented here the focus of this thesis is now concerned with how the users of the system interacted with each other when using it, which forms Chapter 5 of this thesis.

5 Methods

5.1 Introduction

Following the creation and subsequent deployment of the WiiConcept software (see Chapter 4 of this thesis) an experiment was designed to examine the impact of mode of input and configuration on type and frequency of interaction occurring in small group collaborative construction of concept maps. The design of this experiment will be discussed shortly. However, it is necessary at this point to note, when considering the impact of mode and configuration of input on levels of interaction, that both subjective and objective measures have already been applied to the measurement of interaction in both similar studies and similar areas of research e.g. Vogt et al. 2004, and Birnholtz et al. [2007] and Do-Lenh et al. [2009]. Whilst these mixed methods have been applied initially to both mode of input and means of input, the present study differs in that it applies these methodological approaches to discover how participants interact with each other when constructing concept maps in the context of a large-screen projection, and using an interface where gestures are both enabled and disabled. The resultant focus of these mixed methods is, therefore, concentrated upon how input configuration, in the context of mode of input, impacts upon group process, interactions within groups and group social dominance.

The participants were controlled for each experimental group and condition by age, gender and race to eliminate the known effect upon influence and interaction by these variables. The experimental conditions were subsequently manipulated to vary mode of input within groups and configuration between groups. As a result, the aim was to examine how these different configurations affected the participants' level of interaction and social dominance.

Three types of measures were then considered as a means of exploring these experimental objectives, guided by the work of Vogt et al. [2004], Birnholtz et al. [2007] and Huang [2002]. These measures were:

1. Task measures: e.g. individual contribution to concept map.

2. Subjective measures: e.g. perceived influence, perception of the quality of negotiation with the input technology as context, smoothness of discussion, and evaluation of each other's dominance.

3. Process measures: e.g. individual dominance of interactions and conversation, and number and type of Interactions based upon Bale's Interaction Process Analysis (IPA) [1950].

Having outlined the proposed initial framework, it is now necessary to outline the experimental design, subject selection, procedure, task, data capture and finally the data analysis. This Chapter will conclude with the description of the Interaction Process Analysis.

5.2 Experimental design

5.2.1 Step one

Aim: *To create an experiment that considers the impact of mode of input (gestures enabled/disabled) and controller configuration (number of controllers) on group interaction when constructing concept maps (see hypotheses in Chapter 1).*

Approach

The experiment considers the levels and types of interactions (based on categories defined by Bales' IPA) of pairs constructing a series of concept maps in a co-located collaborative large-screen-based ubiquitous environment. The variables used in consideration of these levels and type of interactions are mode of input and configuration of input. Or, more simply, the mode being with or without gestures and configuration being the number of controllers used (in this case one or two-controllers).

The experimental design consisted of a single between-groups factor of input configuration of two levels (one-controller and two-controllers) and a single within-groups factor of interaction style, consisting of two levels (controller(s) without gestures enabled and controller(s) with gestures enabled).

The factor of interaction style was fully counterbalanced with each set of pairs completing only one concept map using the controller configuration (without and with gestures enabled). Indeed, to ensure that there were no confounding variables i.e. between that of input configuration and mode of input, input configuration is the only variable changed between groups and interaction style the only variable changed within groups.

Subsequently, pairs of participants were matched by year of study, and randomly assigned to the mapping conditions. The pairs were then asked to complete one experimental condition either:

1. One WiiRemote controller (with gestures (see Figure 5.1a) and without gestures, (see Figure 5.1b).

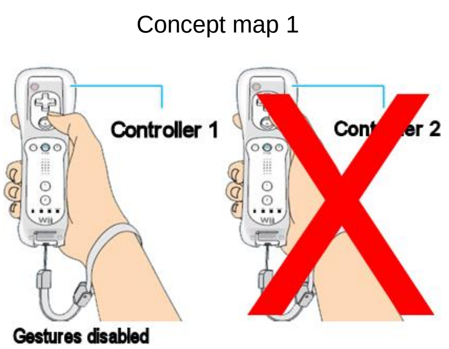


Figure 5.1a: 1 controller without gestures

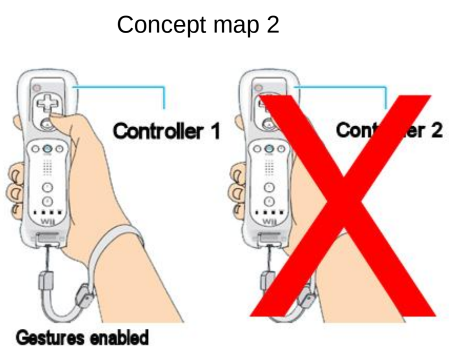
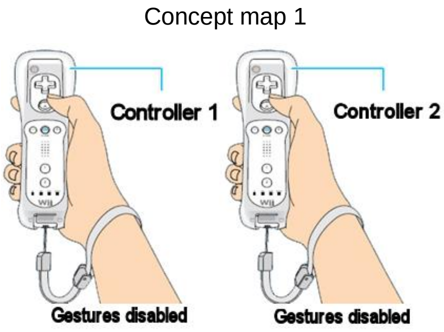


Figure 5.1b: 1 controller with gestures

<u>**or**</u>

2. Two WiiRemote controllers (gestures disabled (see Figure 5.2a) followed by gestures enabled (see Figure 5.2b)).



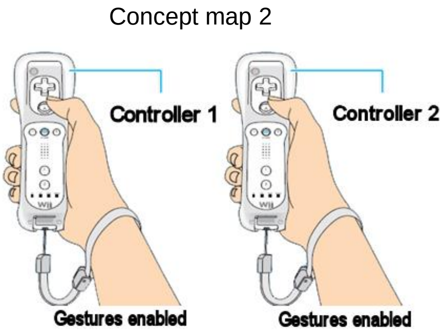


Figure 5.2a: 2 Controllers without gestures   Figure 5.2b: 2 Controllers with gestures

Therefore the experimental conditions were as follows:

Single controller condition (Figure 5.1a and 5.1b): These groups were provided with a single controller placed to the side of the participants before the experiment began. No explicit roles were assigned and it was up to the group to decide who would pick up the controller and use it. The participants were then asked to construct two concept maps, one without gestures followed by another concept map with gestures enabled. As Figure 5.1a and 5.1b shows these pairs only had one-controller between them (as indicated by the red x) and used the controller first without gestures and then with gestures.

Two-controllers condition (Figure 5.2a and 5.2b): A separate series of pairs (those that did not complete the single controller condition) were provided with one-controller each, with each controller manipulating a uniquely-coloured cursor on the screen, which moved based on the data received from the relevant controller. In contrast to the one-controller condition, as described in Figure 5.1 these pairs had use of two-controllers, however, they approached the experiment in the same way as the one-controller condition. These pairs again created a concept map first without the use of gestures followed by a concept map with gestures enabled. Therefore, the ordering of the task and conditions through which the tasks were attempted were not manipulated.

To summarise, each set of groups was assigned to a condition of 1 controller or 2 controllers and then completed a concept map for each condition gestures/ no gestures, allowing for the comparison of pairs who completed the one-controller condition (without and with gestures) and the two-controller condition (without and with gestures). This experimental set-up therefore allows for the between-groups factor of input configuration to be compared as expressed by the horizontal lines shown in Figure 5.3 as well as the within-groups factor of interaction style as indicated by the vertical line shown in Figure 5.3. These within groups' factors also apply to the either one or two-controllers.

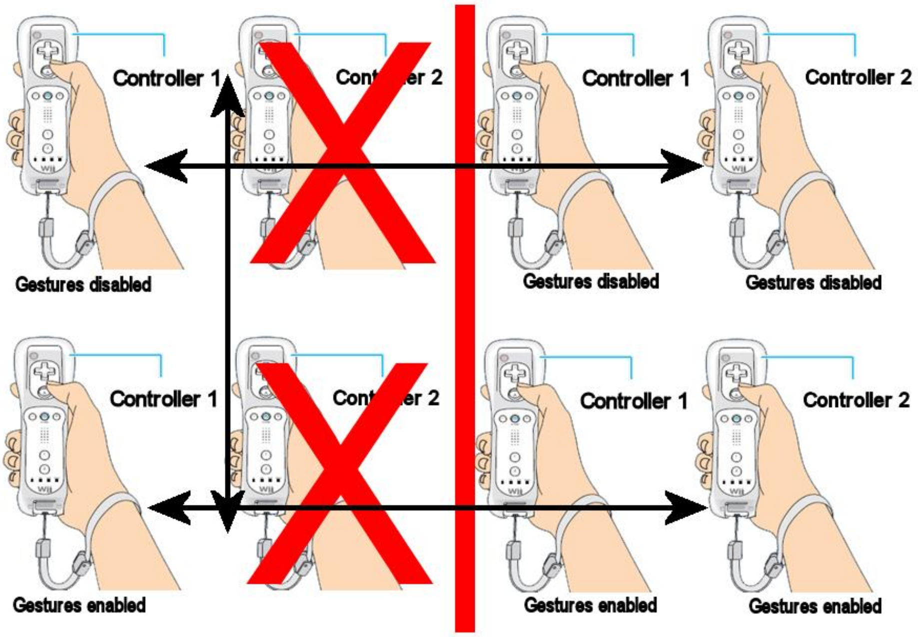


Figure 5.3: Diagram depicting the comparability of variables, within and between groupings for one and two-controllers and with and without gestures.

Rationale

When considering the design of the experiment it was important to consider the control of and operationalising of the variables. Therefore, it was important at this point to consider how such variables have been controlled and considered in similar experiments which have manipulated controller configuration and/or controller interaction style in their use with large screens.

Birnholtz et al. [2007] considered a within-subjects design when considering input configuration and group process in a negotiation task using a large display. Twelve groups completed a mixed-motive negotiation task under two conditions: a single, shared mouse and one mouse per person. Therefore, input configuration was manipulated within the groups as they undertook the experiment. On the other hand, when considering collaboration with group pointer interaction Vogt et al. [2004], in their formal experimental design, constructed 'a single between-groups factor of group size, consisting of three levels (one person, two people and three people), and a single within-groups factor of interaction style, consisting of two levels (mice and laser pointers)… with the factor of interaction style fully counterbalanced [with] groups completing one [task as a mouse] and one [task] using laser pointers'. From this latter experiment it is clear to see that when considering multiple variables careful attention must be given to their control both between and within groups so that any manipulation of the experimental condition must be counterbalanced. Consequently, the established approach when considering multiple variables in this area is to follow a within and between-subjects design as per Vogt et al. [2004], with viable and valuable results achieved through the use of a within-groups design used by Birnholtz et al. [2007].

The objective of this research outlined in this thesis was to create a method and experimental design that considered the impact of mode of input (without and with gestures enabled) and controller configuration (number of controllers) on group interaction when constructing concept maps. Therefore, the rationalisation of the experimental design was grounded in this need. Whilst having considered the designs of related experiments i.e. both mode of input and means of input, this research examines how the groups collaborate and interact with each other around the display when constructing concept maps, with gestures and without. In particular this research considers, how input configuration impacts upon participant's influence on the group and perceived social dominance. With this in mind the experimental design consisted of a single between groups factor of input configuration of two levels (one-controller and two-controllers) and a single within-groups factor of interaction style, consisting of two levels (controller with no gestures enabled and controller with gestures enabled). As with the Vogt et al. [2004] study, the factor of interaction style was fully counterbalanced with each section of groups completing one concept map using the controller configuration without and with gestures enabled, and always in that order.

Alternate experimental designs, ordering, and neutralising learning curves

One alternative to the design chosen might have been to manipulate the ordering of the use of the controllers, i.e. to alternate between gesture conditions, rather than keeping this factor consistent across all conditions. This would therefore allow for any factors of familiarity learnt across the experiment when using the controller on the number and amount of interactions occurring when creating each concept map within condition.

This experimental design would require the formation of six groups that would complete each experimental condition as outlined previously in figure 5.3. Where this experimental design would differ to the one proposed and completed would have been in the ordering of the controller usage see table 5.1.

	One controller		Two controllers		
Groups	6		6		Groups
3	no gestures	gestures	no gestures	gestures	3
3	gestures	no gestures	gestures	no gestures	3

Table 5.1. Alternate experimental design.

In this experimental design groups 1 to 3 would complete the experiment with one controller. Therefore they would construct a concept map, with no gestures and then another different concept map with gestures. Groups 4 to 6 would then complete the experiment for one controller usage, however they would use gestures first for the first concept and then they would not use gestures for the second concept map. This experimental design would have then been completed for the second side of the experiment (i.e. two controller usage) for the remaining 6 groups for a cross comparison between the two sets of six groups. However, controlling for this ordering opens up further questions surrounding ordering. If one criteria of ordering in this case is considered, then further sets of ordering must also be considered, otherwise this would not be a fair comparison when considering this factor of ordering. Ordering would also need to be considered with regards to the ordering of the concept maps themselves. In this way does the ordering of concept map 1 and concept map 2 affect the experiment when completing no gestures, followed by gestures? However, if this were to be considered problems of learnability surrounding the use of the concept maps occur through the familiarity gained through the process of concept mapping itself. At the same time as the variables increase so does the requirement for increased participants to meet these requirements for extra experimentation.

Additionally this alternative design potentially reduces the power of within experiment comparison as the manipulation of the ordering of gestures within groups does not take into account the ordering of the number of controllers. If a consideration of the ordering of gestures occurs then within groups a consideration of controller ordering would also have to be undertaken. Therefore the groups would have to repeat the experiment multiple times increasing learnability through concept map familiarity or extra groups would be required to counteract this learnability. Learnability of the process of concept mapping must also be considered when accounting for ordering.

The selected approach was beneficial in that it dramatically reduced the number of experimental conditions required to complete the experiment and therefore the number of overall participants required for each research condition. This is because in ensuring that groups 1 to 6 for example complete a concept map with gestures disabled, and then enabled with one-controller, they did not then have to repeat the entire experiment with two-controllers, effectively completing four conditions. If they counterbalanced the ordering of gesture usage within groups, the experimental condition would have been complicated by the need to account for controller ordering within groups. The experiment as a comparison between groups and within groups resulted in a within groups change of mode of input and a between groups manipulation of configuration. Taking any ordering of gesture usage into account would have reduced the power of the between groups factor of configuration.

Whilst it is important to consider the ordering of mode of input, any consideration of ordering factors would have required an analysis of the ordering of controllers which would have increased experimental complexity, learnability through increased concept map variability and increased experimental time exposed to the processes of concept mapping and using the WiiRemote. At the same time, as an extension to this experiment it would be useful, with an increased subject selection to investigate the impact of ordering of mode and configuration of input on these group interactions. However, as the participants received the same amount of training for each mode of input it was felt that this factor was counterbalanced without the need for reducing the power of the results obtainable by the participants or increasing the experimental complexity. Familiarity as to the use of concept mapping was varied in that different concept maps were used. At the same time the participants had the same amount of time to familiarise themselves with the controller without and with gestures. Any exploration of this would require groups to vary the order of the concept map and the gestures for each controller condition, not just the mode of input and to do this would mean 4 concept maps and increased familiarity of the concept mapping process.

The process of completing four concept maps instead of two would contribute to the learnability and therefore system familiarity. By the time, the participants had constructed four concept maps the frequency of their interactions as well as the type of their interactions could have been impacted upon through their ability to construct concept maps, which they had first learnt how to use when using one-controller, which would influence their subsequent usage should they have then switched to two-controllers. In making the variable of input configuration a between groups factor any similarities or differences could be seen across the groups otherwise input configuration and mode of input would have been manipulated. As a result it is necessary to control the manipulation of the controllers within groups to ensure that comparisons can be made; otherwise multiple variable changes would have occurred had this not been considered. Ordering of mode of input could be considered within-groups, but should also then include the ordering of other variables (increasingly complexity and the number of participants required).

5.2.2 Step two

Aim: *Subject selection*

Approach

Participants were recruited via e-mail and also via face-to-face discussions in Computer Science classrooms, as part of the convenience sampling strategy followed (and not because they may be more technologically orientated). These students were more easily accessible than any other student sample, and any future research may wish to consider the impact of less technologically orientated participants. As such, the sampling method used was opportunity or convenience orientated in nature.

A University was used as it provided a readily accessible population base of Computer Science students and, due to financial and time constraints, the feasibility of extending the population beyond that of one locality was not possible. Therefore, the target population of the study was the total number of Undergraduate students studying Computer Science (excluding Natural Science students) at Durham University. As of the academic year 2008/2009 there were 143 undergraduate Computer Science students with 48 yr one students, 60 year two students and 35 year three students.

In total twenty four participants were used totalling twelve groups with six groups assigned to each experimental condition, e.g. groups 1 to 6 to Figure 1 and groups 7 to 12 to Figure 2. Students were also provided with a financial incentive to participate.

Rationale

The number of participants selected is comparable to the number used in the Vogt et al. [2004] experiment comparing modes of input in small groups with large screens and is also the same number of groups used in the Birnholtz et al. [2007] study. The overall population of Computer Science students or participants available was one hundred and forty three, with a participatory rate of 16.78%. Whilst precision increases significantly as the sample size increases, as with all research, there is a trade off between size of sample and time and cost. As the number of participants has been replicated in similar experiments, the total number of participants provides an excellent basis through which to compare with other similar sized experiments.

5.2.3 Step three

Aim: *Setup and equipment*

Approach

The experiments were conducted in the Technology Enhanced Learning Research Classroom in the Department of Computer Science at a University. Participants stood in front of a projected image of the concept mapping software (as discussed in the previous Chapter), at a distance of three metres. The projected display size was 2.03 x 1.5 m (6.66 x 4.92 ft).

The participants were provided with Nintendo WiiRemote wireless controllers which were handed to each participant, and when one-controller only was provided the controller was placed on a small table to the right of the participants so that they could decide who initially had control over the use of the Nintendo WiiRemote controller.

The Nintendo WiiRemote controllers communicated with the laptop using a generic WIDCOMM compatible Bluetooth Dongle, using BlueCove version 2.03.

For the recognition of the gestures the Wiigee_v11 library was used, with WiiRemoteJ_v1.5 used as the API for the software that was subsequently created as part of the research. Details of the hardware are discussed/ can be found in Appendix 1.

5.2.4 Step four

Aim: *Construct a task that allows participants to create a series of concept maps in the varying experimental conditions.*

Approach

Unlike prior studies that have explored input configuration and group process e.g. Birnholtz et al. [2007] and Gutwin and Greenberg [2002] who have used newspaper based tasks, and even where interaction style has been compared (mice and laser pointers) e.g. Vogt et al. [2004] (where two mazes were provided to find the shortest paths between two points) the task that the students completed focused on the collaborative construction of a series of concept maps depicting module content, learning outcomes, prerequisites of knowledge and key skills for two first-year and two second-year undergraduate modules.

In light of the experimental conditions, the task, therefore, included a consideration of the mode and form of input of configuration upon the collaboration of the participants when they construct concept maps. As a result, this task was chosen as a means of exploring what impact the input configuration and mode of input had, if any, on the collaborative group processes of small groups when constructing concept maps in this way. Therefore the resultant concept maps, as will be discussed shortly, are useful to any evaluation in this context; however, the concept maps are not the focus of the research, rather how the groups construct them and the impact of the mode of input and configuration on their ability to work in groups when doing so. The scoring of concept maps in this way is a widely debated topic in the wider field of concept mapping research e.g. Ruiz-Primo and Shavelson [1996] Kinchin [2000], Klein, Chung, Osmundson, Herl, & O'Neil [2001] and McClure, Sonak, and Suen, [1999], and Rye & Rubba, [2002].

With the experimental design ensuring that groups 1 to 6 used one-controller within their individual pairs and groups 7 to 12 had a controller each, the need to vary mode of input within groups ensured that each pair was required to create two concept maps. The concept maps the pairs were asked to construct considered the following (see Appendix 2 for a full task description):

- module content i.e. their interpretation of the syllabus;
- their understanding of what they have learnt from the modules and what they expect to learn in the future;
- their understanding of the key skills that they feel that they have acquired from the modules that they have studied or are about to undertake.

Computer Science students at a University in the UK undertook a series of compulsory and optional modules throughout their period of study. To determine the modules that would therefore constitute the task's content, random selection was applied to the first year compulsory undergraduate modules, with the second year equivalent compulsory module used as the comparison between the two modules. The Computer Systems I (CSYS) and Introduction to Programming (IP) / Programming and Data Structures (PDS) modules were the modules that were randomly selected. The second year follow on module to Computer Systems I was Computer Systems II, with the second year follow on module for IP/PDS being Software Applications (SA).

Having selected the task's module content as being computer systems I and II for the first concept map and IP/PDS and Software Applications for the second concept map, the pairs first completed a concept map for each. Therefore, and irrespective of experimental condition, the groups were first asked to complete a concept map for the Undergraduate Computer Systems I and II modules (see Figure 5.4):

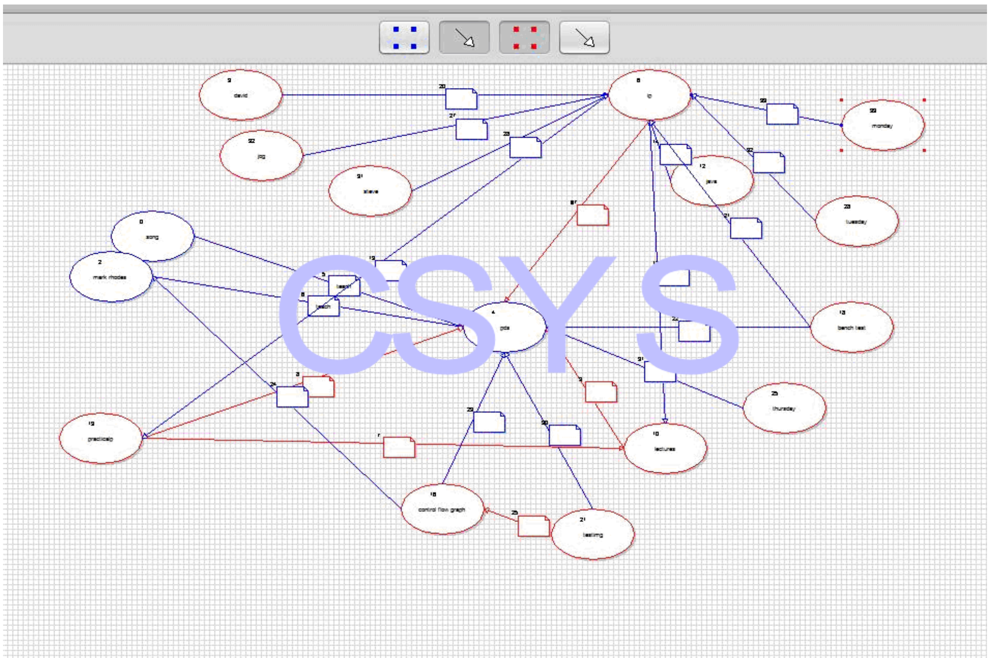


Figure 5.4: Diagram depicting an example concept map for the CSYS I and II computer science modules.

Having completed a concept map for Computer Systems the participants were then asked to complete a concept map for the Undergraduate IP/PDS and Software Applications modules (see Figure 5.5). Therefore the order of concept mapping would not change; either the pairs created a concept map for Csys I and II using a one-controller or two-controllers without gestures or they created a concept map for IP/PDS and Software Applications with one or two-controllers with gestures enabled.

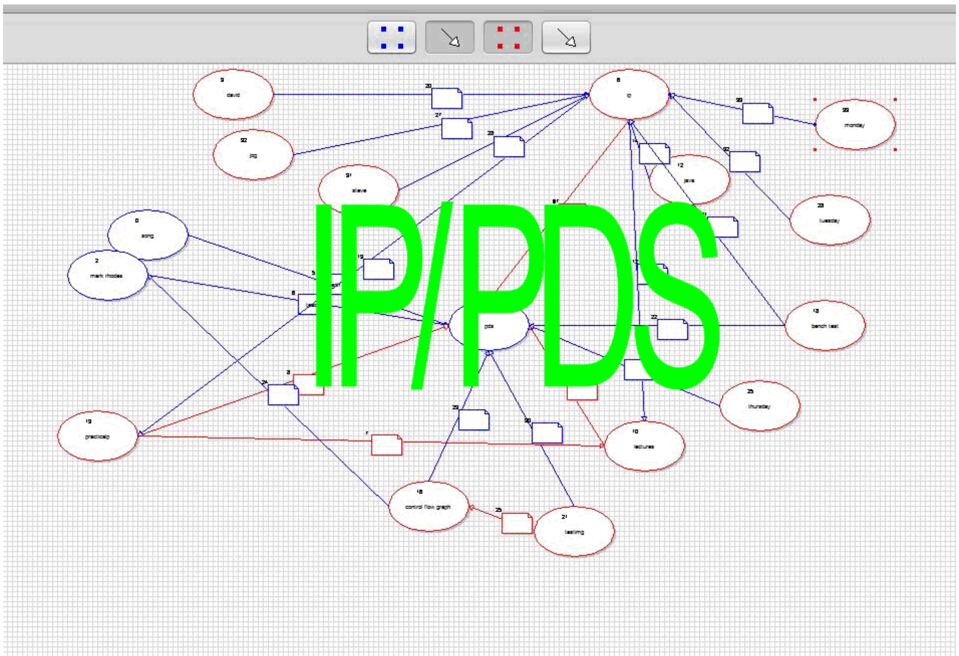


Figure 5.5: Diagram depicting an example concept map for the IP/PDS and Software Applications computer science modules.

The task was completed in the same order to reduce the number of participants required to carry out a complete run through of the experiment. Changing of the ordering of the task was not necessary as the task was to construct the concept maps and not to analyse what they had created. Also, the ordering of the with gesture or without gesture conditions also remained unchanged. It is possible that there may be a personal preference for one module over another for students but the task itself remained the same - that of co-constructing a concept map and task impact was evaluated post-test to measure any impact task may or may not have had.

The task itself did not require that any participant should be a leader. The participants were free to pass the controller between each other (that is, if they had only one-controller between the two participants in the group). Additionally, participants had the shared goal of constructing and laying out the concept map and therefore the task was intended to be a reflection of their combined understanding of the domain of knowledge.

Rationale

Knowledge construction and visualisation techniques to support learning are not as prevalent in Higher Education in the UK as research promoting their benefit suggests they should be, e.g. 'if concept mapping is so helpful to learning Biology, why aren't we all doing it?' [Kinchin, 2001]. At the same time motivation to use them is low [Farrand et al, 2002] and in their present form not always 'received positively by students or their teachers' [Santhanam et al. 1998]. Thus, Barenholz and Tamir [1992] found that students who volunteered to use concept maps 'were not all eventually in favour of its use'. With conceptual mapping struggling in this seeming milieu it provides a suitable context through which to explore how input configuration and mode of input impact, if at all, upon participants' attitudes to and use of concept mapping. As a result, the concept mapping tasks provided a means through which participants could explore this idea of module interactivity and content.

The promotion of the successful comprehension of module structure and interrelation and the active construction of this understanding using novel interaction techniques may help students to engage and interact with Computer Science courses.

5.2.5 Step five:

Aim: *Procedure*

Approach

Whilst mixed methods have been used in wider HCI research to attempt to measure interaction, and also within both Birnholtz et al. [2007] and Vogt et al. [2004] (studies which begin to explore input configuration and mode of input respectively) the use of such mixed measures will be applied in a new context and incorporating different methods i.e. IPA. This will be incorporated into exploring and subsequently determining how groups use the large-screen display when constructing concept maps, using singular or multiple controllers without gestures and with gestures, and in particular, their subsequent impact upon group interaction and perceived levels of influence and social dominance. The questionnaires and the mixed method approaches are discussed in section 5.3 with the remainder of this section describing what the participants were required to complete for each experiment.

Prior to beginning the experiment and before they had arrived participants completed a consent form and Interview Agreement (see Appendix 3) and also the associated video release form (see Appendix 3).

Having completed these initial consent forms, the participants were also asked to complete the pre-test questionnaire, which was designed to ascertain their prior computer and peripheral usage (particularly that of the WiiRemote) as well as their prior use of and context of conceptual mapping (see Appendix 4). This pre-test document also asked the participants to complete the dominance scale questionnaire (see Appendix 5).

The participants had also been provided with the experimental task before they arrived as well as the controls for the system and instructions as to how to complete a concept map (see Appendix 6).

On arrival, participants were shown to the Technology Enhanced Learning Research Classroom. Prior to beginning the experiment, and having received the completed pre-test questionnaires, the students were asked firstly if they had any questions with regard to the experiment and the task to be undertaken and were then requested to read the task sheet.

Having read the task sheet the students were then provided with a ten minute overview of concept mapping (see Appendix 6). The participants were then provided with an explanation of the controls of the system (see Chapter 4) for five minutes.

The participants were then allowed to explore the system for a further five minutes (five minutes each if one-controller was used between them) before completing the first task.

After the first task (the CSYS I to CSYS II concept map), the participants were requested to complete a post-test questionnaire which assessed how they perceived both they and their partner had worked (see Appendix 7). When completing this questionnaire the participants were seated at opposite sides of the room to prevent collusion. The time allocated to complete the first task was thirty minutes.

Having completed the questionnaire, the students were then asked to complete another concept map (the IP/PDS to Software Applications concept map). However, before doing so they were provided with a five minute introduction with regards to the controls of the system, as well as five minutes to explore the system and its use with the gestures. Finally, the participants completed a questionnaire outlining their use of the system as well as the mode of interaction used (see Appendix 8). As with the first task the second task was allocated thirty minutes.

To summarise therefore, six groups (1 to 6) each with two participants constructed two concept maps; one with one-controller with gestures disabled, and one with one-controller and gestures enabled. The task remained constant in that it was to construct a concept map as did the ordering of conditions.

Six further groups (7 to 12) repeated the above procedure with each participant having their own controller and completed the tasks in the same way as in the first half of the experiment. Therefore, formally the experiment design consisted of a single between groups factor of input configuration of two levels (one-controller and two-controllers) across the two sets of groups and a single within-groups factor of interaction style, consisting of two levels (controller with no gestures enabled and controller with gestures enabled). The factor of interaction style was fully counterbalanced with each section of groups completing one concept map using the controller configuration without gestures and one with gestures enabled. Following the experimentation participants were interviewed using semi-structured interviews.

5.3 Experimental method:

Having outlined the research context and the proposed research aims it is necessary to consider how these questions will be answered experimentally and also how the variables controlled in the experimental design will be measured. As such, this analysis will now focus on what it is that is actually being measured, and how it needs to be measured.

Where necessary, reference will be made to methodological approaches used in the relevant research that have also considered the measurements that will be undertaken in this research. The remaining outline of this experimental method will then consider the process of data capture as well as data analysis.

5.3.1 Data capture:

This section outlines the methods undertaken through which the data was captured when completing the research.

Mixed methods have been used widely in wider HCI research to attempt to measure the impact of input configuration upon group process, e.g. Birnholtz et al. 2007, and mode of input e.g. Vogt et al. [2004] as well as in terms of the effect of camera angle upon group discussion (Huang [2002]). These studies provide a sound basis upon which the following processes of data capture are based. These processes take the form of both subjective and objective measures which have been applied to the measurement of interaction and social dominance within small groups both in relation to similar studies and similar areas of research.

Whilst these mixed methods have been applied initially to both mode of input and means of input the present study examines how the groups use the display when constructing concept maps, using gestures disabled and enabled, and in particular, how input configuration and mode of input impacts group processes and levels of interaction as well as perceived social dominance.

5.3.2 Pre-test questionnaires:

The pre-test questionnaires consisted of:

1. An adapted demographic and HCI-use questionnaire developed by Smith [2009], (a description of these adaptations follows in the rationale of these pre-test questionnaires below).

2. A social dominance assessment questionnaire based on scales developed by Burgoon et al. [1998], and refined by Huang [2002] and Birnholtz et al. [2007].

Rationale

The questionnaire adapted from Smith [2009], has been used to elicit demographic data as well as pertinent information in the study of HCI devices. Therefore, questions concerning the following have been included: year of study, handedness, perceived friendliness level of group partner, computer peripheral and frequency of use (especially prior usage of the WiiRemote), as well as prior usage of Conceptual Mapping Software (see Appendix 4).

The social dominance assessment questionnaire has been used as it is an established and well used form through which to assess group and individual perceptions of social dominance. It has also been used previously in the context of input configuration, in relation to a study of input configuration and group process in a negotiation task using a large display e.g. Birnholtz et al.

[2007] and was also therefore easily adaptable for use here. Therefore, the assessment scale could be used for the first time to the application of a conceptual mapping task and measure interpersonal dominance as a behavioural, relational and interactionally orientated state 'that reflects the actual achievement of influence or control over another via communicative actions' [Huang, 2002].

5.3.3 Post-test questionnaires:

The post-test questionnaires consisted of:

1. A further social dominance assessment questionnaire based on scales developed by Burgoon et al. [1998], and refined by Huang [2002] and Birnholtz et al. [2007]. This post-experiment was completed twice – once after each input condition.

2. A final questionnaire, the software evaluation questionnaire was also used. This questionnaire based on the work of Smith [2009] was used to evaluate the software system and the participants' perceptions of non-gesture and gesture usage.

Rationale

The social dominance assessment post experiment instrument, in contrast to the pre-test questionnaire, asked the participants to assess their own behaviour as well as that of their partner. As such, this post-test questionnaire was completed twice – once after each input condition. This post-test questionnaire was also divided into two sub-sections. These sections were as follows:

1. The first section was formulated with questions that were intended to provide a basis through which to determine the participant's assessment of the quality of discussion, the quality of communication,

as well as the perceived contribution of their partner and whether or not anybody emerged as a leader.

2. The second section consisted of two sets of social dominance scales used in the assessment of perceived social dominance of the participant in relation to the task as well as that of their partner. This measure was developed by Burgoon et al. [1998] and used in conjunction with input configuration by Birnholtz et al. [2007].

Such an approach, therefore, allows for a consideration of any difference between self-perceived and group perceived dominance.

The Software evaluation questionnaire was based on the study completed by Smith [2009], which was constructed to evaluate the use of software in conjunction with peripheral devices and virtual environments. As a consequence the type of evaluatory questions were similar in nature, however, the questionnaire was modified to rate the difficulty of constructing the concept map in each condition, the participant's level of attentiveness, and ability to remember gestures (broadly clustered around the notion of concept mapping), their own and their partner's contribution to the group task (group work), task and environmental influences (see Appendix 8).

5.3.4 Event logs:

As part of the mixed methods triangulatory approach undertaken, data was also recorded in the form of event logs, which is consistent with the research undertaken in this field.

Approach

A log file was written into the software, which recorded the movement undertaken by the controller, i.e. where a node was moved to, the user who carried out the event, who created the conceptual node and/or edge, the word that was entered in the node, and whether it was edited or not, what deletions were made to the concept map and by whom, and how many times the participants zoomed in and out.

For the single controller condition, the experimenter recorded each time the controller was switched between users, which allowed for the ability to determine how long each participant controlled the controller. It would therefore be possible to determine who then did what with the controller when in possession of it.

Rationale

Such underlying objective data provides a useful source of information through which to verify and compare to the participant's self perception. This data can then be further verified through a comparison with any group perception. For example, where a participant is asked to describe their contribution to the concept map, it is possible to corroborate this perception with an objective measure provided by the event logs i.e. whether they did in fact contribute more in terms of number of nodes than edges when they had said that they did so.

In summary, therefore, the mixed method approach outlined here, which is grounded in related research provides a robust basis through which to explore the hypotheses stated at the beginning of this Chapter. Having outlined the protocols used for similar experiments and the experiment undertaken here it is now necessary to consider the metrics obtained from the experimental method. Therefore, the remainder of this section will outline the main areas of investigation and the principal metrics obtained.

5.4 Measures

Three types of measures were collected from the experimental method, which it has been shown earlier in this Chapter have been guided by the work of Vogt et al. [2004], Birnholtz et al. [2007] and Huang [2002].
These measures are:

1. Task measures: e.g. individual contribution to concept map.

2. Subjective measures: e.g. perceived influence, perception of the quality of negotiation, smoothness of discussion, and evaluation of each other's dominance.

3. Process measures: e.g. individual dominance of interactions and conversation, number and type of interactions based upon Bale's Interaction Process Analysis.

Having briefly outlined the form of these measures it is now necessary to discuss them in details in the sections to follow.

5.4.1 Task/objective measures:

Participants were asked to rate how easy or difficult they found it to complete the task for each module requested . As such this would provide a useful measure as to whether there was any difficulty beyond the use of the mode of interaction, which was elicited in the questions asking the participants to rate the level of ease or difficulty in constructing the concept map for Computer System I and II as well as IP/PDS and Software Applications. These questions were then quantified by the use of a Likert scale (1 to 7), ranging from easy (1) to difficult (7).

When considering the measurement of the mode and configuration of input and their impact upon the concept maps created the objective measures provided by the event logs were used to determine for example how many nodes were created. In terms of measuring the completed task i.e. the completed concept map, the measures of number of nodes constructed was applied as well as the number of links between nodes. This would then provide an insight into task influence upon social dominance (i.e. the number of nodes created), if more nodes were created by one participant there may be a dominance in task, which would, in contrast to any other affordance measure, such as number of utterances or types of interaction identified through Interaction Process Analysis, identify dominance. The number of nodes created therefore represent the number of nodes attributable to an individual, with each individual node forming an idea or expression that constitutes the final concept map.

Further objective measures were also recorded in the event logs. The movement of the WiiRemote controllers was identified to ascertain who was responsible for the construction/layout of the completed conceptual maps, as it is possible that an individual could have been responsible for this within the group. Therefore, conceptual nodes could be identified and traced to where they were moved to. Additionally, screen captures were taken of the completed conceptual maps to further aid in the understanding of the group processes which created them, which also provide a visual measure of the construction of the completed concept maps i.e. their visual complexity.

The decision was made to exclude any consideration of individual and group expertise when constructing the concept map due to the arbitrary nature of applying scores in the context of concept mapping to the task.

5.4.2 Subjective post-test measures:

5.4.2.1 Perceived influence

Perceived influence was measured in the post-test social dominance questionnaire. The participants were asked to assign a percentage to indicate their partner’s influence over the final map as per Huang [2002] and Birnholtz et al. [2007]. The subject's influence was then determined from the remaining percentage subtracted from one hundred. However, rather than relying on this one measure, perceived influence was also assessed in the evaluation of the software questionnaire, whereby participants were asked to consider both their and their partner's contribution to the construction of the concept map. This was subsequently completed for both concept maps that were created i.e. select the statement which bests describes your contribution to the concept map for computer systems I and II and subsequently IP/PDS and Software Applications. The participants were asked to assess their perceived contribution using seven options, with a typical option taking the form of; 'I created more nodes than links' for example. Such an approach also provides measures of the overall group construction of the concept map, as influence can also be seen in terms of control in the overall concept map. Additionally influence was assessed in terms of their mode of input, i.e. their perception of contributory influence when in possession of the controller in its various modes, see Figure 5.6.

Did you feel more you contributed more if you were in possession of the controller when the controller was enabled:

a. with gestures?

☐	☐	☐
Yes	**No**	**No difference**

b. without gestures?

☐	☐	☐
Yes	**No**	**No difference**

c. I was never in possession of a controller

Figure 5.6: Question used post-test to assess self-perceived contribution when using the controller(s) with and without gestures.

At the same time, influence can also be attributed to the process of completing the task, e.g. the influence espoused throughout the task and also in terms of influence in conversation. These measures will be discussed shortly.

5.4.2.1 Impression formation and social dominance

The social dominance assessment post experiment instrument based on scales developed by Burgoon et al. [1998], and refined by Huang [2002] and Birnholtz et al. [2007] was used to measure these phenomena. The dominance scale was composed of five dimensions:

- *Influence:* The perceived degree of impact a participant has on others in winning them over to his or her point of view.

- *Panache:* The perceived memorability and stylishness of a person's communication style.

- *Trust*: The extent to which a person is perceived as reliable and truthful.

- *Poise:* The extent to which a person is perceived as able to make decisions and take decisive action.

- *Self assurance:* The perception of a person’s confidence.

The sum of these scores is then taken as a measure of dominance. To assess the performance of the social dominance scales Cronbach’s α was used which is ‘a measure of the internal correlation and reliability of the items that comprise a construct’ Birnholtz et al. [2007]. For a detailed explanation of this measure see section 6.1 in the results chapter.

Additionally, the social dominance assessment post-experiment instrument also asked the participants if anybody emerged as group leader. Furthermore, measures could also then be considered in terms of whether these 'leaders' behaved differently, particularly with regards to controller usage, when gestures were disabled and then enabled.

Critically, these social dominance measures obtained in the assessment questionnaires can then be considered in conjunction with the measures obtained from the Interaction Process Analysis (IPA) [Bales, 1950] as a further consideration in terms of dominance of conversation and type and number of interactions. This measure will be discussed in more detail when detailing the IPA measure.

Rationale

Ercison and Roger [1973] have proposed a coding scheme, for example, to analyse the level of dominance and submissiveness in an interpersonal relationship from an interactional However, Ericson's coding scheme has been described as being too mechanistic in manner [Huang, 2002]. In the context of this finding, Burgoon et al. [1998] define interpersonal dominance as a relational, behavioural and interactional state reflecting the actual achievement of influence or control over another via communicative actions. Indeed, when considering the measurement of perceived social dominance, Burgoon et al. [1998, cited in Birnholtz 2007] 'developed and validated a set of questionnaire scale items for measuring social dominance that consists of the following constructs:

- *Control of conversation:* The extent to which any participant in a group or dyadic negotiation is perceived to monopolize the conversation and take charge.

- *Influence:* The perceived degree of impact a participant has on others in winning them over to his or her point of view.

- *Panache:* The perceived memorability and stylishness of a person's communication style.

- *Trust:* The extent to which a person is perceived as reliable and truthful.

- *Poise:* The extent to which a person is perceived as able to make decisions and take decisive action.

- *Self assurance:* The perception of a person's confidence' [Birnholtz et al. 2007].

.

Huang [2002], therefore, proposes that to measure social dominance effectively, there is a need to combine the codification of social dominance in a less mechanistic manner than the processes provided by Erickson, with the more easily modifiable assessment scales developed by Burgoon et al. [1998]. Indeed, such an analysis has been used in the measurement of social dominance in the context of input configuration and its use with a large display as proposed by Birnholtz et al. [2007]. It is for that reason, that the codification scheme proposed by Burgoon et al. [1998], and refined by Huang [2002], and used in the context of a similar experiment by Birnholtz et al. [2007] has been used to elicit information as to the impact of input condition on perceived social dominance. However, this perception is not limited to that of the participants but is reinforced by the codification of the participant’s speech.

5.4.2.2 Perception of group discussion

To evaluate the quality of discussion process the participants were asked to rate:

(1) the quality of discussion;

(2) the effectiveness of the discussion and;

(3) the outcome of discussion on a seven-point Likert scale as part of the social dominance assessment post experiment instrument see figure 5.7.

1	The overall quality of the discussion was	poor	1	2	3	4	5	6	7	excellent
2	The discussion, on the whole, was	ineffective	1	2	3	4	5	6	7	effective
3	The outcomes of the discussion were	unsatisfactory	1	2	3	4	5	6	7	satisfactory

Figure 5.7: Question used post-test to assess perception of group discussion when using the controller(s) with and without gestures.

5.4.2.3 Usefulness of developed technology

To evaluate the usefulness of the developed WiiConcept conceptual mapping software, participants were required to answer a series of questions designed to illicit this information based on the questionnaire developed by Smith [2009].

The participants were subsequently asked to rate their level of preference when using the controller without-gestures as a mouse for constructing the concept map and with gestures when creating a concept map. They were also asked to rate the level of ease or difficulty in constructing the concept map with the varying controller conditions and the form of these questions is shown by figure 5.8.

Please rate the level of ease or difficulty in constructing the concept map with the controller for Computer Systems I and II

Without gestures

	☐	☐	☐	☐	☐	☐	☐	
(easy)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**(difficult)**

Please rate the level of ease or difficulty in constructing the concept map with the controller for IP/PDS and Software Applications

With gestures

	☐	☐	☐	☐	☐	☐	☐	
(easy)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**(difficult)**

Figure 5.8: Example questions used to assess the perceived ease or difficulty of concept map construction when using the controller(s) with and without gestures for each concept map.

At the same time, measures were also considered and collected as to any dependent influences which may occur or be likely to impact on the experiment. These measures therefore considered:

(1) the level of attentiveness/level of focus displayed when constructing each of the concept maps;

(2) the ease/difficulty in being able to complete the gestures required of them;

(3) the ease or difficulty in being able to create the gestures;

(4) the appropriateness of the gestures assigned to the actions;

(5) how easy or difficult they found it to complete the task for each concept map (based on task);

(6) whether or not there was sufficient time to complete the task; and

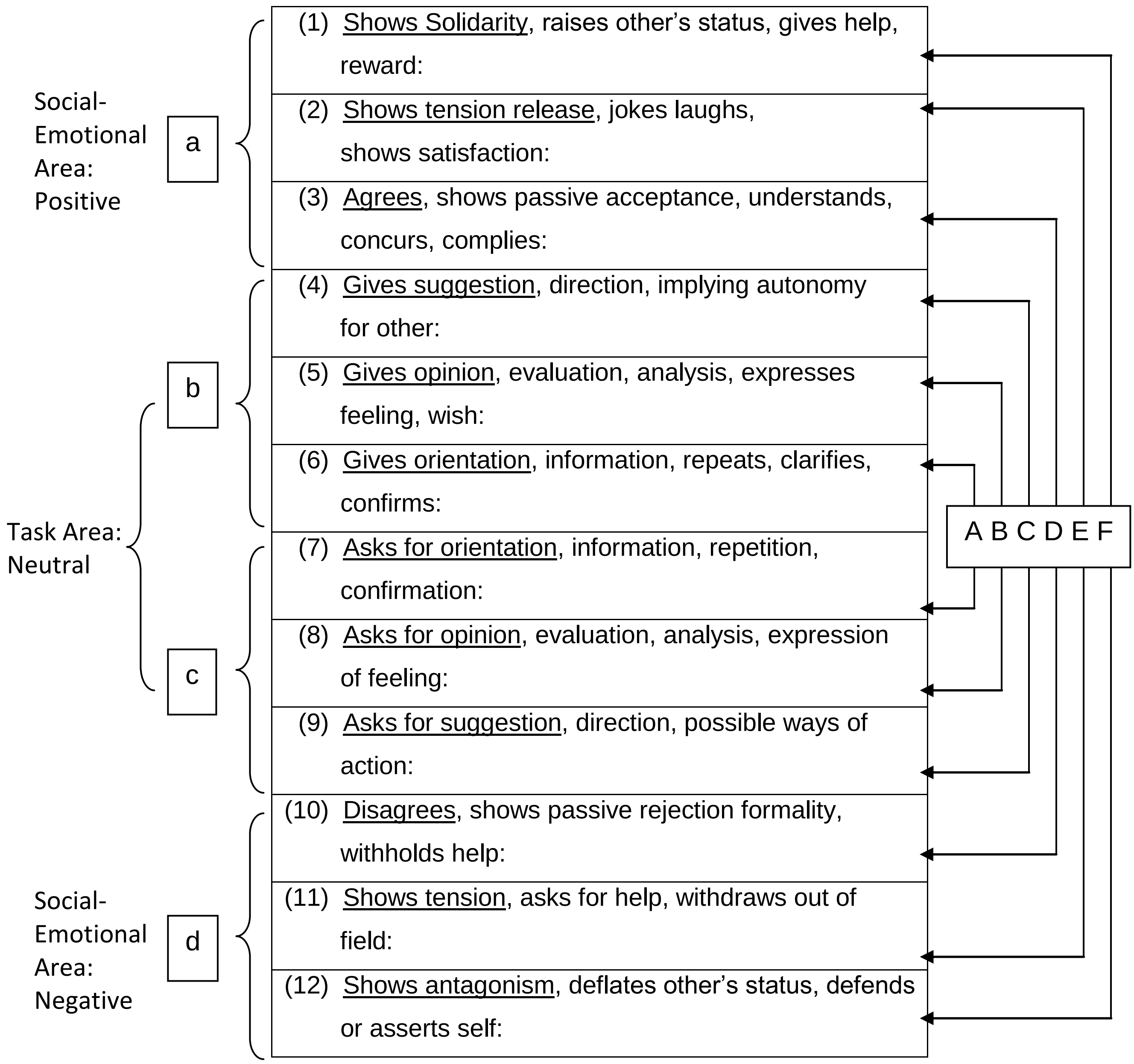
(7) whether any factor disturbed or distracted them. Measures (1 to 5) were Likert scale based questions using scales of agreement appropriate to each question, whereas measures (6 and 7) were yes or no questions.

5.4.3 Interaction process analysis (IPA)

The experiments were recorded using multiple ceiling mounted video cameras which recorded all participatory activity for each experimental condition. As the aim was to consider the effect the experimental conditions had on the participants' levels and type of interaction and the level of social dominance occurring within these interactions the video and auditory information was transcribed using Interaction Process Analysis.

Interaction Process Analysis provides a series of measurable categories through which to classify communication patterns and their subsequent classification into types of interactions that occur in small group situations. As such, these classifications are orientated around the premise that group success is dependent upon how well the group can complete the task asked of it (the task function) and how satisfied the group can keep its members when completing this task (the socio-emotional function). Bales has therefore identified and developed twelve interactional categories (see figure 5.9), which are incorporated into four main categories:

- socio-emotional positive (shows solidarity, tension reduction, agreement);
- socio-emotional negative (shows antagonism, tension, disagreement);
- task-related attempted solutions (gives suggestions, opinions, orientation); and
- task-related questions (asks for suggestions, opinions, orientation).



Key:

a Positive reactions
b Attempted answers
c Questions
d Negative reactions

A Problems of communication
B Problems of evaluation
C Problems of control
D Problems of decision
E Problems of tension reduction
F Problems of reintegration

Figure 5.9: System of categories used in observation and their major relations.

With these categories identified, the unit to be scored can be identified, which has been identified by Bales, in its simplest form, as a single simple sentence or its equivalent that is used in conversation [Bale 1950]. As a result, the act of communication, either verbal or non-verbal, constitutes the interaction itself. Therefore, the sets of categories used within the analysis focus on complete units of meaningful communication as a single sentence, which can then be categorised by the observer (see Table 5.1). Complex sentences (as distinguished from these more simple sentences) will therefore include more than one IPA category score. The encoder in this instance (see Figure 5.9), interprets the sentence 'shall we write the things that we've learnt?' as being of interaction category (9) as described in figure 5.9. With the direction of the conversation moving from person 1 to 2 i.e. {(8)1-2}. This can further be categorised as being a question (task area neutral (c) as per figure 5.9) hinting towards problems of evaluation (see figure 5.9). Indeed, each dependent sentence can receive a separate score if it expresses an additional complete thought (see Table 5.2, line 5, Timespan 0.39 to 0.42).

Table 5.2 Example coded transcript

	Timespan	**Content**
1	0:00.0 - 0:27.1	You go first this time {(4) 2-1} Ok {(3) 1-2} {1 in possession of the controller}
2	0:27.1 - 0:33.5	Its side to side this one {(4) 1-2} huhmmmm {(5) 2-1}
3	0:33.5 - 0:35.4	Cool {(2) 1-2}
4	0:35.4 - 0:39.0	Shall we just do the modules again like we did earlier? {(8) 1-2}
5	0:39.0 - 0:42.7	Like the names? {(7) 1-2} Shall we write the things that we've learnt? {(9) 2-1}
6	0:42.7 - 0:47.6	Yeah {(3) 1-2} What did we learn? {(8) 1-2} Can you remember what we learnt? {(7) 2-1} Laughter {(2) 0-0}

Having encoded these sentences the measures of interaction, therefore, are the categories of interaction as determined by the observer in relation to figure 5.9. The determining of when these categories apply to the sentence under study by the observer at any one time is guided by Bales Category descriptions and therefore a major skill required of the observer is the ability to be familiar with these categories of interaction; with some of these categories readily describable and others that may be more complex and more difficult to comprehend and identify. Any given interaction that is to be encoded should be placed in one and only one category; where any confusion exists Bales has established two priority rules with which to resolve any conflict:

1. View each act as a response to the last act, or as an anticipation of the next act.

2. Favour the category more distant from the middle. Classify the act in the category nearer the top or the bottom of the list.

At least one observer codes each participatory group member and scores occurrences of each interactional category as they occur.

The main use of IPA in this context is to ascertain the amount and types of interaction that occur when manipulating the variables of mode and configuration of input when using accelerometer based devices in the context of collaborative concept mapping. Therefore the application of Bales' IPA concentrates on the coding of these categories and their occurrence. Further research may consider how conflict occurs through the categorisation of these verbal indicators, and explains why this exploration of conflict factors has not been included in this thesis. When studying conflict, in this context, it is important to look for the categories of behaviours that indicate both the presence and absence of conflict, when pairs interact when concept mapping. For example, the researcher might have analysed the number of statements implying both agreement and disagreement among group members determining at what points they occurred. The researcher could also have identified instances where group members show support for competing viewpoints or proposals and contrast those with examples of group members voicing support for the same position. Ellis and Fisher [1975] studied group conflict in these ways, using Fisher's coding scheme, however such an investigation is beyond the remit of this thesis.

Rationale

Use of Interaction Process Analysis

As this research is concerned with investigating the impact of the configuration and mode of input upon levels of interaction and their effect upon levels of social dominance, IPA provides a useful method through which to categorise these interactions. Interactions could then be clustered around category to see how the groups were interacting, the amount of interaction they were carrying out as well as the type of interaction. This classification metric allows for the determining of the interaction that occurred, rather than the counting of words which may suggest an interaction (out of the context), as defined by the process of content analysis, or (in context) through discourse analysis.

Critically, the technique of content analysis has come under criticism in some quarters for the decontextualisation of words from the discourse being examined. Billig's [1989] criticism is typical: 'This sort of methodology can count words, but it cannot interpret them. Under some circumstances mere counting can lead to misleading conclusions.' Therefore, many researchers argue that there is a need for the integration of content analysis with other approaches to textual analysis in modern linguistics which resulted in the formation of Discourse Analysis.

As such, the level of vocabulary is clearly important in the analysis of discourse, but, as Billig's criticism suggests, words in discourse may only be interpreted precisely in the context in which they occur [Wilson, 1998]. Discourse analysis is thorough and comprehensive, but it is very time consuming. It also requires specialist linguistic knowledge. Content analysis on the other hand is well established as a social research technique but it is a decontextualised method.

Exclusion of non-verbal communication

The term 'non verbal' is commonly used to describe all human communication events that transcend the spoken or written word [Fabri et al. 2002]. Non-verbal is important in communication as it 'typically serves to repeat, contradict, substitute, complement, accent, or regulate verbal communication' [Knapp, 1978]. As such, Interaction Process Analysis has been criticised for overemphasising spoken communication and failing to consider the important role of nonverbal communication.

Argyle [1988] contests that non-verbal behaviour takes place 'primarily through facial expression, bodily contact, gaze (and pupil dilation), spatial behaviour gesture, clothing and appearance, body posture, and non-verbal vocalisation'. Indeed, 'when two parties interact, they monitor and interpret each other; semitonal expression [Strongman,1996]; [with] hundreds of expressive movements employed every day as part of the social interaction events of a typical day [Morris, 1979] and their correct use is an essential part of our social competence and skills' [Fabri et al. 2002].

For example, Lindley et al. [2008] measure participant's 'verbal and non-verbal behaviours' using coding definitions based on the Autism Diagnostic Observation Schedule [Lord et al. 2000]. Verbalisations were categorised as 'speech or other utterances (e.g. laughter and groans), and the length of time that each participant spent producing speech and other utterances was measured' [Lindley et al. 2008]. Critically, however, non-verbal behaviours were also classified according to two categories. 'Instrumental gestures were defined as those in which the action conveys a clear meaning or directs attention (e.g. pointing, shrugging, and nods of the head). Emphatic gestures were defined as those in which the action is emotive (e.g. placing the hands to the mouth in shock)' [Lindley et al. 2008].

Having defined these gestures the author tallied the number of gestures in both categories and summed them to give a score for each pair. Therefore, speech and utterances were recorded as well as instrumental and emphatic gestures. However, the use of non-verbal measures was deemed beyond the remit of this research, as individual investigations of non-verbal behaviour could be considered as the main focus of any individual investigation i.e. the effect of bodily contact or body posture on social dominance. It is therefore not possible to account for every type of non-verbal behaviour as it becomes increasingly difficult to know where to draw the line, for example, if the researcher looks at eye movement, then they should perhaps also investigate heart rate. Indeed, the undertaking of the analysis of non-verbal communication would require expert knowledge in terms of the ability to read people's non-verbal behaviour to a level which promoted consistency.

5.5 Data analysis

The focus of the data analysis is concerned with the data obtained from the mixed method approach previously outlined. Therefore, the data collected is quantitative in nature e.g. pre- and post-test questionnaires, as well as qualitative in nature through the use of semi-structured interviews and the encoding of the IPA (which when encoded became quantitative).

The environment through which the IPA analysis was completed consisted of NVivo qualitative software (see Figure 5.10). This environment was chosen as it provides an accurate transcription facility whereby snippets of conversation can be controlled to the sentence level of conversation. Once the video has been paused the conversation can then be encoded with the video located to the left of the transcription. Therefore, it is possible to ensure that the correct IPA category is applied as it occurs at the exact point of interaction. This is particularly useful as when dealing with two people interacting it is necessary to see how one person reacts to the stimulus of the other which, realistically, can only be achieved in small blocks of analysis. With the information encoded from the video information, the number of occurrences of each interaction type can be counted, and with the time-stamping function the type and number of interactions can be considered over time.

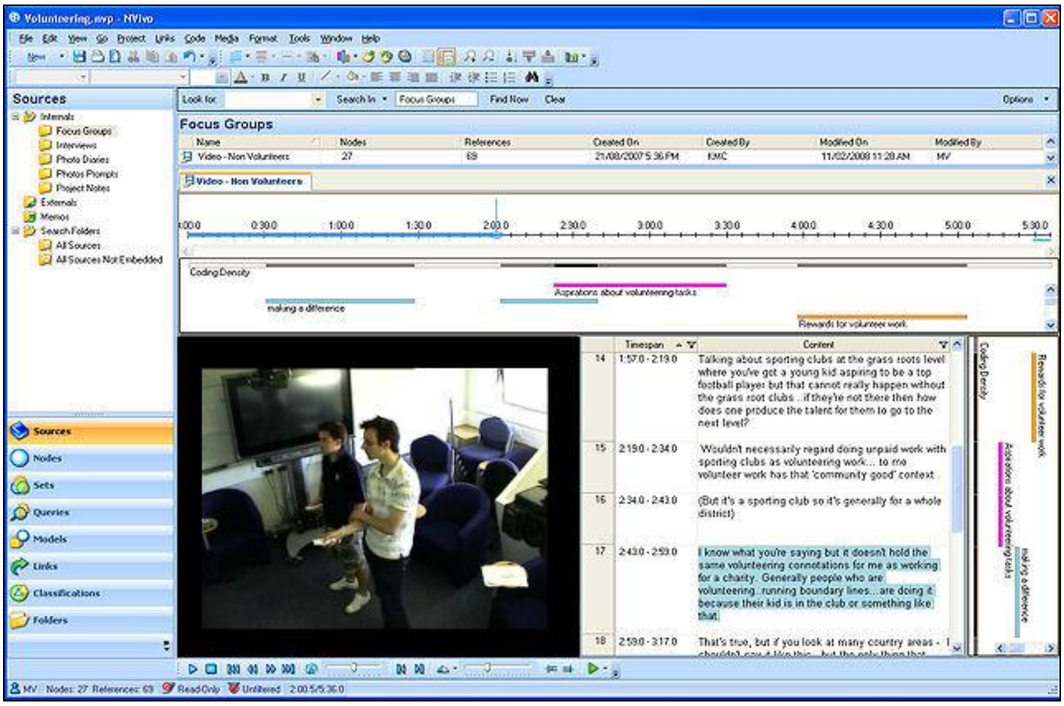


Figure 5.10: NVivo 8 qualitative analysis environment

Having accumulated the data into quantitative form through the use of NVivo, and also following the initial transformation of the questionnaire and log event data so that it was grouped in terms of experimental condition, any further analysis would be completed through the statistical SPSS package. However, before completing such an analysis it is now important to consider the overall approach to the analysis as well as any checks prepared for the initial data analysis.

The initial data analysis followed the preliminary steps of:

1. data cleaning;

2. initial data analysis (assessment of data quality);

3. the main data analysis (answering the original research questions);

4. and any further data analysis (i.e. any additional analyses).

These initial transformations have been in included in the results Chapter (see Chapter 6) of this thesis for more detailed information.

5.5.1 Data cleaning and assessment of quality of data

Data cleaning

The total number of groups after data cleaning was reduced from twelve to eleven in total, with five groups completing the one-controller condition, with variable method of input and six further groups completing the two-controller condition with variable method of input across the concept maps. This was due to one group using the incorrect mode of input with the associated concept map and hence it would be unfair to compare their map with the remaining experiments. All of the participants were required to complete the experiment in the same order, with the first concept map created without gestures and the second concept map using gestures. This ensured that all experiments were the same, and this experiment, which used gestures for the first concept map and without-gestures for the second, could not be used as it introduced another uncontrolled variable, that of the ordering of input, which would have affected results. The ordering of the controller usage was not controlled for; with regards to the learnability of the controller, as the concept maps that were created, beyond the number of nodes, and edges created was not the focus of the research. The resultant concept maps were a product of the interaction process and therefore were commented upon, and, if a comparison was made of the concept maps, and the forms of interaction used to create them, then the ordering of the concept maps and the controllers would have had to be controlled.

Additionally, the transcribed interactions were counted and divided by the total time to normalise for the small number of groups that completed the task in less than the maximum allowed time. This normalisation was required to allow a fair comparison in that groups finishing earlier may have had fewer interactions due to the fact that they took less time in their opinion to complete the task.

With reference to potential outliers it was identified that one group had one member with dyspraxia, which can result in the partial loss of the ability to co-ordinate and perform certain purposeful movements and gestures and may also affects the planning of what to do and how to do it. As such, this may impact upon their contribution to the group process. Furthermore, two participants were identified as having dyslexia, which may have impacted upon their use of the predictive text system used to enter words into the conceptual mapping nodes and links. These participants were not excluded from the experiment as to do so would have been discriminatory as an open invitation was made for volunteers.

Data integrity

Crucially, all data was fully checked to maintain data integrity. For example, when considering the number of interactions implemented in the video and their type, as well as their distribution over time e.g. ten minute blocks, it was important to ensure that the number of interactions and their type were consistent when considered as a whole and as individual blocks. Therefore, these values were corrected and if there were any inaccuracies the process of identifying these values was repeated until consistency was maintained.

In terms of the log event data the deletion information accrued was discounted as the log inexplicably recorded that a conceptual node or link was recorded, at the same time as a deletion. The final number of conceptual nodes and links were observable from the completed concept map and, therefore, if the final number of nodes and links was consistent in terms of the number of deletions, then the data was valid. However, where some ‘none’ deletions occurred they were in fact node deletions; as such this information could not then be used.

Measurement quality

Analysis of homogeneity (internal consistency), which gives an indication of the reliability of a measurement instrument, i.e. whether all items fit into a unidimensional scale, were used. As the questionnaire data used Likert Scales the variances of the items in the scales were assessed, with the Cronbach's α of the scales, and the change in the Cronbach's alpha determined with scores ≥ 70 being acceptable following approaches used by Birnholtz et al. [2007].

Reliability

It is important to consider the appraisals made by observers when using IPA, therefore to ensure observer reliability IPA has an inbuilt and tested method through which to determine the reliability of categorisation. To ensure reliability of categorisation 10% of the experiments were randomly selected to be encoded by another trained observer and the conformity compared between the two. To determine whether the observer reliability for a particular pair has a probability of .50 or greater ‘and is therefore acceptable’ Bales’ [1950] four conventions are observed. Further analysis with regards to the reliability of the measures and the data collected is discussed in the evaluatory section of this thesis (see Chapter 7).

5.5.2 Threats to validity

There are a number of limitations associated with the research study described in this thesis that restrict the claims that can be made and suggest future directions for research.

It is possible that the opinions derived from the questionnaires may or may not be the accurate representation of what the participants think, rather what they want the experimenter to think. However, and particularly in the case of the social dominance questionnaire, the randomisation of questions and measures which form the social dominance constructs reduce the influence of this factor. At the same time, the pre-test questionnaire may conceivably increase or decrease a subject's sensitivity or responsiveness to any experimental variable and therefore influence their approach to the subsequent experiment, although this is true of any questionnaire. The use of the pre-test questionnaire however, does alleviate prior experience threats to the validity of the results by exploring the influence of prior experience upon the factors under study i.e. the impact of prior concept mapping and use of WiiRemotes on node creation for example.

To increase validity of the results ascertained here the experiments need to be replicated and cross-validated through the use of more groups, studying different courses and across different Universities. This experimental extension should also broaden to include factors of ethnicity, and age, as well as technological competence.

5.6 Summary

In this Chapter the experimental design and the method undertaken to complete the experiment have been described. The variables that constitute the experiment have been limited to the number of controllers and the type of interaction (with or without gestures) so that participants do not have to spend too long completing the experiments or become too familiar with the processes involved. The experiment therefore investigates a single between-groups factor of input configuration of two levels (one and two-controllers) and a single within-groups factor of interaction style, consisting of two levels (controller(s) without gestures and controller(s) with gestures enabled).

Furthermore, the task undertaken and the procedure of undertaking the experiments have also been fully described as well as the methods of data capture. At the same time, the process of IPA has also been described, with a brief discussion of its application in this context as well as the overall process of analysis applied to the experiment. Consideration has also been demonstrated towards maintaining data integrity and reliability with the focus of these discussions to continue in Chapter 6 of this thesis in the context of the experimental results.

6 Results

6.1 Introduction

This Chapter outlines the descriptive and the statistical analysis carried out on the measures shown in Chapter 5 of this thesis. These measures were used to test the main research questions and experimental hypotheses outlined in Chapter 1 of this thesis.

The hypotheses first outlined in Chapter 1 are discussed in association with the main research questions in the following chapter, Chapter 7. The main research questions are summarised here and form the structure of the presentation of the results which constitute this Chapter:

RQ1. Does the number of controllers and with and without use of gestures influence the amount of interaction in a group when constructing concept maps?

RQ2. Does the number of controllers and non/use of gestures influence the type of interaction seen in groups?

RQ3. How does the level of social dominance and controller and gesture configuration influence the amount of interaction in a group?

RQ4. How does the level of social dominance influence the type of interaction in a group?

RQ5. Does the level of social dominance influence who uses the controller first?

RQ6. What is the relationship between amount and type of interaction and the concept map process outcomes?

In this chapter, the overall analytical approach followed is described in relation to each of these questions with these approaches descriptively summarised and then analysed.

The results presented here are drawn from the individual pre- and post-test measures outlined in Chapter 5, section 5.3.1. The subsequent sections of this Chapter also describe the outcomes of these measures. In summary, therefore, each of the subsequent sections that outline the experimental data begin with a general description followed by a summary of the findings. As part of the descriptive results, analysis will be provided in answer to the experimental hypotheses.

6.2 Sample

Participants were twelve pairs of male undergraduate students from the Department of Computer Science. The participants were offered a small monetary incentive to participate in the experiment, having responded to online mailing lists. Six pairs served in the one-controller condition and six pairs served in the two-controller condition. The pairs were randomly assigned, but knew each other as they were all computer science students studying in the same undergraduate year. For a detailed description of the experimental method see section 5.2.

One group in the one-controller condition was excluded from the data because they completed the tasks in a different order to the other groups (i.e. they used gestures followed by non-gestures). Therefore, five groups constituted the data for the one-controller condition and six groups for the two-controller condition. Two groups (one in the one-controller condition and one in the two- controller condition) expressed learning difficulties, namely dyslexia and dyspraxia. These groups were not excluded from the data as to have done so would have been discriminatory.

6.2.1 Demographics

The students (twenty-two in total) were all between the ages of 18-25, white males and were first, second and final year undergraduates. Each pair was matched by their year group to avoid any interpersonal issues that could be attributed to differences in experience that may occur in mixed year groups. The majority of participants were in their second year in the one-controller condition (60% of this condition) and in their first year in the two-controller experimental condition (66.7%), which occurred due to the opportunistic sampling of participants (see Table 6.1).

The handedness of participants meant that there were a larger number of mixed handedness groups in the two-controller condition (83.3%) as opposed to (40%) in the one-controller condition. The remaining groups were all right, right handed combinations. There were no left, left handed groups.

6.2.3 Prior usage of computers

How often groups use a computer with other people in the same room suggests that the majority of groups (80%) do so with a mixture of participants who replied daily or weekly, whereas this was only true of 16.7% of groups in the two-controller condition. In the two-controllers 66.6% constituted groups whereby both participants in that group solely replied to either meeting the criteria daily or weekly. This response was gathered to ascertain the participants' frequency of experiencing of working with others in the same room, i.e. collaboratively. Those that do so might therefore interact differently or be predisposed to interact in a certain way.

Table 6.1 shows the prior use of computers by groups for the frequency of use of a computer with other people at the same time, whereby they would both be using the same computer at the same time. The options available were, daily, weekly, monthly or never. All respondents had used a computer with other people at the same time. Where groups responded with the same response; 40% in the one-controller condition expressed that they did so weekly, with 33.3% expressing that they did so monthly in the two-controller condition.

Table 6.1 Frequency of participant's frequency of use of a computer whereby multiple users use the same computer at the same time.

	1 controller		2 controllers	
	Frequency	Percent	Frequency	Percent
Weekly	4	40	2	16.7
Monthly	0	0	4	33.3
Daily/ weekly	4	40	2	16.7
Monthly/weekly	0	0	2	16.7
Monthly/daily	2	20	2	16.7
Total	10	100	12	100

6.2.4 Prior use of WiiRemote technology

With regards to participants' prior usage of Wii controllers in the one-controller condition all of the participants had prior usage of a controller, whereas this was true of 66.7% of groups in the two-controller condition, with 33.3% of groups having at least one person with prior experience. This factor was important to understand as prior usage of WiiRemotes, might have lead to greater familiarity, and possibly through this familiarity increased interaction. It was, therefore, important to ascertain prior exposure to these controllers and is considered in terms of its affect on amount and type of interaction displayed by the participants in this chapter.

In terms of regularity of use of the controller there was little difference with the majority of respondents using the controller monthly. More frequent use across conditions again might have led to increased familiarity and therefore perhaps increasing the number of nodes created for example. If indeed they were familiar with the process of gesturing then they may have been more likely to be able to gesture, perhaps more quickly and regularly, and therefore by that process have an increased number of nodes.

At the same time most groups had used the controller with other devices other than the Wii. This factor was also considered as the context of the experiment was to use a WiiRemote controller with a pc and a large screen, a setting not normally associated with controller usage. Therefore, it was important to ascertain what possible effect this factor may or may not have.

When considering the usage of a controller with other people across groups the participants generally did not use controllers with other people (see Table 6.2). Again, this was an important variable to investigate as the experiment required participants to construct concept maps using WiiRemotes with others.

As outlined in the procedure (see section 6.2.5), the use of the controller was explained to the participants irrespective of condition. They were given five minutes which to familiarise themselves with the system after they had been provided with an explanation of the controls of the software.

Table 6.2 Frequency of group usage of the WiiRemote controller (pre-test).

	1 controller		2 controllers	
	Frequency	Percent	Frequency	Percent
Neither used	6	60	10	83
1 has used	4	40	2	17
Both used	0	0	0	0
Total	10	100	12	100

6.2.5 Prior use of gestures

The participants were asked to report their skill level of using gestures (whether novice, experienced, or expert). In relation to the one-controller condition 80% of groups were a mixture of those participants who thought they were novice and those who thought they were experienced. In the two-controller condition the groups were either strictly novices (50%) or strictly experienced users (50%). No participant identified themselves as an expert.

The responses to this measure was elicited to understand the possible impact that those who considered themselves expert might interact more, or that groups of experts might lead to more conflict based types of interaction.

When considering the prior use of other forms of gesture-based technology, 40% had not used any form of technology with gestures. In relation to the two-controller condition, 33% had not used any form of technology that included gestures. Prior familiarity of other gesture technology may also provide an advantage over those that had never used gesture-based technology. Therefore, this measure could now be accounted for.

6.2.6 Prior experience of gaming

In determining the impact of prior experience of gaming upon the variables of interest in the hypotheses, the participants were asked a series of questions designed to assess their self-perceived gaming habits. In the one-controller condition 60% had both participants in each pair respond that they played computer games regularly. For pairs in the two-controller condition 17% responded that they played computer games regularly, with a further 67% of groups having at least one group member who played computer games regularly. It was important to ascertain this prior experience of gaming as the controllers associated with the experiment are based in gaming, with the process of gaming perhaps influencing their potential ability to interact with and use software based systems.

Such a consideration also led to the following pre survey measure whereby the participants were asked to consider their self perceived ability in relation to computer games. 60% of groups in the one-controller condition considered themselves to be either experienced or expert in their ability, whereas this was true of 50% of groups in the two-controller condition (see Table 6.3).

Table 6.3 Frequency of participants self perceived skill at playing computer games.

	1 controller		2 controllers	
	Frequency	Percent	Frequency	Percent
Experienced	4	40	2	17
Novice/ experienced	0	0	4	33
Experienced/ expert	6	60	6	50
Total	10	100	12	100

In terms of the prior usage of controllers with a selection of the most popular game systems: 40% of groups in the one-controller condition used controllers regularly (i.e. at least once a week) with six or more games systems, while this was true of 17% in the two-controller condition. It is possible that increased prior use of controllers with other games systems may also lead to a predisposition to using controllers in general. Therefore, it is also useful to see how this impacts, if at all, upon their ability to use WiiRemote controllers in the context of the experiment. For example, if they use a lot of different types of controllers with different games systems are they more or less likely to interact more frequently with each other and in different ways when constructing concept maps?

6.2.7 Prior experience of concept mapping

When asked if the participants had any prior experience of concept mapping none of the groups in the one-controller condition had any prior experience. In the two-controllers condition 67% did not have any experience of concept mapping (see Table 6.4). Such a measure was important to consider as the task to be undertaken by the participants was to construct a concept map. Therefore, it was important to ascertain if the participants had any experience to see what impact, if any, this variable had on the overall findings of the experiment i.e. was any result influenced by their prior level of experience with concept mapping?

Table 6.4. Frequency of participant's prior usage of concept mapping.

	1 controller		2 controllers	
	Frequency	Percent	Frequency	Percent
No experience	10	100	8	67
Experience	0	0	4	33
Total	10	100	12	100

With regards to the frequency of use of concept mapping, 33% expressed that they used concept mapping software monthly in the two-controller condition. Again, higher frequency of use of concept maps may increase their familiarity with them and aid them in their construction of the concept map. Therefore, it is important to ascertain where any changes in the sample population occur and to subsequently test their likely effect.

Crucially, having identified those participants that have experience of concept mapping it also necessary to ascertain how skilled they think they are and also whether or not they have received any instructional training with regards to concept mapping. In terms of self perceived skill level at concept mapping 67% expressed that they had no expertise in concept mapping in the two-controller condition, with 17% of participants having a novice level of skill, with one group having at least one person being experienced. Of these, 17% received instructional training with concept mapping in an educationally/work-orientated context in the two-controller condition. Such measures are useful when considering the amount of nodes that are created in the concept map as it is possible that those with formal training will have less cognitive loading as they do not have to assimilate as much information.

Additionally, none of the groups have ever used concept mapping software collaboratively with large-screen projected displays. This measure was also important as the pairs would all be using concept mapping software in this context. Therefore, without understanding their prior experience, for example, it would be impossible to say if any recordable change in the experimental condition was due to a change of a controlled variable or whether or not they had been regular prior users of concept mapping software in the context of large displays.

6.2.8 Social dominance constructs

During the pre-test questionnaire (see section 5.3.3 for the post-test measures), participants rated eighteen Likert scale items designed to assess levels of social dominance. This social dominance assessment pre- and post-experiment instrument (see section 5.4.2.1 for more detail) was based on scales developed by Burgoon et al. [1998], and refined by Huang [2002] and Birnholtz et al. [2007]. The scales were between 1 (strongly disagree) and 7 (strongly agree) (see Appendix 5).

Having collected the participants' responses to these social dominance constructs, social dominance scales based on these measures were calculated. To do this, the scales were based on the factor analysis completed by Burgoon et al. [1998], who provide a series of factors through which to measure social dominance via poise and influence, conversational control, panache and self-assurance.

The factors that were applied were:

(1) *Control of conversation* – The perceived extent through which the participant or dyad, appeared to take charge and monopolise the conversation.

(2) *Influence and poise* – The extent to which a group member is perceived to be able to make decisions and take decisive action, as well as their perceived ability to persuade people over to his or her own point of view;

(3) *Self assurance* – The perceived level of group members' confidence.

These scales as identified above were then tested for reliability to determine the best fit of the pre-test measures to the social dominance scales. To measure the reliability of the social dominance scales Cronbach's α was used, which is 'a measure of the internal correlation and reliability of the items that comprise a construct' Birnholtz et al. [2007]. The application of this test to the pre-test social dominance data resulted in alpha scores of between 0.601 and 0.77. The alphas for these scales are presented in (see, Table 6.5).

Table: 6.5 Cronbach's alpha for social dominance constructs

Construct	**Cronbach's alpha**
Influence and Poise	0.77
Conversational Control	0.663
Self-Assurance	0.601

Values of 0.7 or above are generally regarded as acceptable levels of reliability. The measures are independent of each other and thus not related.

6.3 Group interaction

Having described the pre-test results and the social dominance constructs the focus of this chapter now shifts to the analysis of the hypothesis driven questioning collected via the IPA measure described in section 5.4.3 of this thesis.

6.3.1 Amount of interaction

Following the transcription of the video material the transcripts were coded using Bales' *Interaction Process Analysis* Bales [1950] (see section 5.4.3). The total number of interactions for each pair was summed and a group total of amount of interaction was then provided (see section 5.4.3 for information regarding the definition of an interaction).

As there was some variance in the time taken to complete the task the total number of interactions for each pair were normalised by dividing the total number of interactions by the amount of time undertaken and multiplying it by thirty (the allotted time for the experiment).

H1a: It was hypothesised that:

- *Groups would exhibit higher amounts of interaction when using one-controller as opposed to two.*

H1b: It was also hypothesised that:

- *Groups would exhibit higher amounts of interaction when using gestures rather than without gestures.*

The descriptive statistics for the total number of interactions with regards to experimental condition are presented in Table 6.6.

Table: 6.6 Descriptive statistics for mean total number of interactions by IPA category for controller configurations.

Controllers	Gestures	Mean	SD	# of participants
1	No	383.29	81.74	
	Yes	482.07	83.61	
	Total	432.68	93.74	10
2	No	250.52	137.20	
	Yes	370.03	127.76	
	Total	310.27	140.97	12
Total	No	310.87	129.97	
	Yes	420.95	119.92	
	Total	365.91	134.41	22

6.3.1.1 Controllers and amount of interaction

To explore *H1a* a one-way Analysis of Variance (ANOVA) was conducted to evaluate the relationship between the number of controllers and the total number of interactions that occurred. The independent variable, the number of controllers, included two levels: one and two-controllers. The dependent variable was the total number of interactions. The ANOVA indicated a main effect of number of controllers, $F(1,18)=6.38$, $p=0.02$, with a higher number of group interactions when pairs had one-controller (M=432, SD=93) than two-controllers (M=310, SD=140).

As part of the ANOVA, the use and non use of gestures was also considered with a main effect of gestures also evident, $F(1,18)$, $p=0.04$, with more interactions occurring with gestures (M=420, SD=119), than without gestures (M=310, SD=129).

The interaction effect was not statistically significant.

Figure 6.3 shows the total mean number of interactions for all groups by experimental condition, indicating that within-groups for one-controller the mean total number of interactions for all groups increased from 383 to 482 with the number of interactions increasing from 250 to 370 for two-controllers. Therefore, groups in the two-controller condition, even with gestures (370) only begin to approach the lower number of interactions (383) witnessed by groups who use one-controller without gestures, (see Figure 6.1).

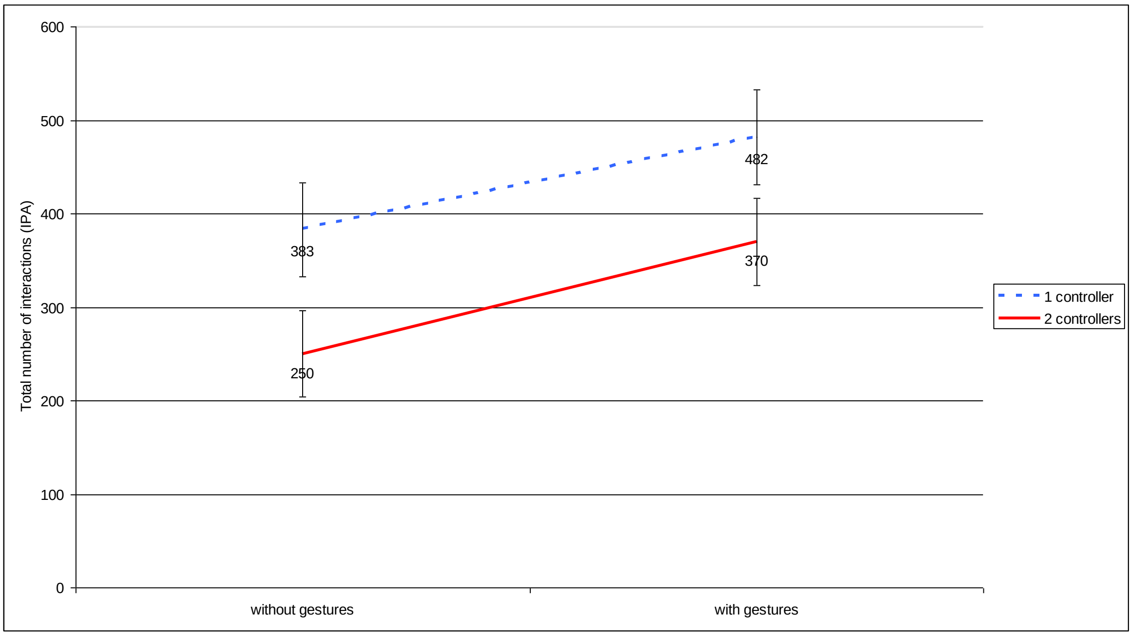


Figure 6.1: Total mean number of interactions by condition.

6.3.1.2 The influence of prior experience factors on the amount of interaction

Analysis of variance was completed for all of the pre-test measures outlined at the beginning of this Chapter and are summarised here:

(1) An Analysis of Variance indicated that there was no significant main effect of prior experience of concept mapping on the amount of interaction for either condition. There were also no interaction effects.

(2) An Analysis of Variance indicated that there was no significant main effect of prior WiiRemote usage on the amount of interaction for either condition. There were also no interaction effects.

(3) An Analysis of Variance indicated that there was a significant main effect of frequency of use of WiiRemote controllers on the amount of interaction, $F(3,10)=5.417$, $p=0.018$. The mean amount of interaction for groups with weekly users of the WiiRemote was (M= 570), monthly (M= 321), and monthly/weekly (M= 363). There were no interaction effects.

(4) An Analysis of Variance indicated that there was no significant main effect of handedness on the amount of interaction for either condition. There were also no interaction effects.

(5) An Analysis of Variance indicated that there was no significant main effect of group year on the amount of interaction for either condition. There were also no interaction effects.

(6) An Analysis of Variance indicated that there was a significant main effect of perceived skill at gesturing on the amount of interaction, $F(2,14)=5.071$, $p=0.022$. The mean amount of interaction for groups with novice users of gestures was novice (M= 328), experienced (M= 399), and a mixture of novice and experienced (M= 432). There were no interaction effects.

(7) An Analysis of Variance indicated that there was no significant main effect of prior usage of other gesture-orientated technology upon the amount of interaction. There were no interaction effects.

6.3.1.3 Summary

Higher levels of all interaction were associated with one-controller, so results indicated that one-controller afforded higher levels of interaction, with gestures also increasing the number of interactions seen. At the same time, there was a main effect of perceived skill at gesturing and the frequency of use of controllers with regards to the amount of interaction that occurred. There were no other influences.

6.3.2 Type of interaction

Types of interaction were coded using Bales' scheme exploring whether there were differences in the type and amount of each interaction type for each experimental condition. As this was a transcription of video based interaction, it was not possible for the coder to do this 'blind'.

To ensure that the coding was not biased by the potentially subjective coding a second person coded 10% of the material as described in section 5.5.1 of this thesis. This coder was external to the Computer Science department and therefore was not familiar with the participants or their interactions. Comparison between the two coders showed no significant difference in the classification of category of interactions.

H2: It was hypothesised that:

- *Groups in the single controller condition would experience more discussion of group process. As such there would be higher amounts of interaction for task area neutral areas categories as determined by Bales' IPA e.g. Gives opinion and orientation, than the two-controller condition where groups would act in their own best interest in the multi controller condition. Because it is expected that more interaction will occur when using gestures as opposed to non-gestures, groups in the single controller condition with gestures will elicit the highest scores in these areas.*

- *Consequently, with single controller groups more likely to discuss group process, it is expected that they will show higher levels of solidarity and lower levels of tension when using one-controller as opposed to two-controllers. In the two-controller condition it will be expected that there will be less group discussion in relation to opinion and orientation and, therefore, there will be increased levels of tension and antagonism.*

- *Where increased levels of tension and antagonism will be at their highest will be with gestures as opposed to without gestures for both one and two-controllers. The use of gestures will see increased levels* *of socio-emotional area negative categories of interactions, as groups struggle to use gestures. However, whereas negotiation is likely to occur when using one-controller as to who may be 'best' at gesturing, it is likely that with a controller each more socio negative interactions may occur as one user may be 'better' at gesturing than another. Therefore, interactions of these types will be highest for two-controllers with gestures as there will be less group process discussion, and as a consequence less group solidarity will be displayed and, therefore, more group antagonism, disagreement and tension expressed in interaction in these categories.*

The descriptive statistics for the total number of interactions by category of interaction are presented in Table 6.7.

Table: 6.7 Descriptive statistics for mean total number of interactions by IPA category for controller configurations.

Category of Interaction (IPA)	Controllers	Gestures	Mean	Std. Deviation	#
Shows solidarity	1	No	10.63	5.731	5
		Yes	18.28	5.450	5
		Total	14.45	6.637	10
	2	No	4.89	4.640	6
		Yes	7.69	5.536	6
		Total	6.29	5.083	12
	Total	No	7.50	5.732	11
		Yes	12.50	7.602	11
		Total	10.00	7.051	22
Shows tension release	1	No	39.05	9.628	5
		Yes	56.95	15.805	5
		Total	48.00	15.532	10
	2	No	21.75	9.546	6
		Yes	45.09	25.389	6
		Total	33.42	21.978	12
	Total	No	29.61	12.815	11
		Yes	50.48	21.460	11

		Total	40.05	20.287	22
Agrees	1	No	32.20	14.820	5
		Yes	35.94	14.980	5
		Total	34.07	14.186	10
	2	No	27.21	15.291	6
		Yes	34.37	21.393	6
		Total	30.79	18.119	12
	Total	No	29.48	14.544	11
		Yes	35.09	17.868	11
		Total	32.28	16.156	22
Gives suggestion	1	No	27.42	15.728	5
		Yes	28.91	16.738	5
		Total	28.16	15.332	10
	2	No	21.24	11.239	6
		Yes	25.89	7.883	6
		Total	23.56	9.569	12
	Total	No	24.05	13.135	11
		Yes	27.26	12.067	11
		Total	25.65	12.418	22
Gives opinion	1	No	89.98	24.504	5
		Yes	109.90	19.320	5
		Total	99.94	23.303	10
	2	No	74.58	59.662	6
		Yes	113.33	46.295	6
		Total	93.96	54.787	12
	Total	No	81.58	45.658	11
		Yes	111.77	34.988	11
		Total	96.68	42.595	22
Gives orientation	1	No	68.89	23.709	5
		Yes	95.46	11.983	5
		Total	82.17	22.580	10
	2	No	36.42	19.175	6
		Yes	46.62	20.142	6
		Total	41.52	19.490	12
	Total	No	51.18	26.383	11

		Yes	68.82	30.183	11
		Total	60.00	29.099	22
Asks for orientation	1	No	40.38	12.370	5
		Yes	39.64	3.294	5
		Total	40.01	8.543	10
	2	No	19.61	5.874	6
		Yes	28.28	15.104	6
		Total	23.95	11.829	12
	Total	No	29.05	14.004	11
		Yes	33.44	12.391	11
		Total	31.25	13.098	22
Asks for opinion	1	No	30.89	12.331	5
		Yes	34.11	15.339	5
		Total	32.50	13.230	10
	2	No	15.18	10.142	6
		Yes	21.87	9.204	6
		Total	18.53	9.871	12
	Total	No	22.32	13.398	11
		Yes	27.43	13.318	11
		Total	24.88	13.296	22
Asks for suggestion	1	No	7.50	6.500	5
		Yes	2.09	2.003	5
		Total	4.79	5.355	10
	2	No	2.74	2.556	6
		Yes	1.76	1.619	6
		Total	2.25	2.103	12
	Total	No	4.90	5.132	11
		Yes	1.91	1.716	11
		Total	3.41	4.035	22
Disagrees	1	No	7.95	1.553	5
		Yes	8.90	5.151	5
		Total	8.43	3.621	10
	2	No	4.12	3.474	6
		Yes	6.72	4.420	6
		Total	5.42	4.026	12
	Total	No	5.86	3.317	11

		Yes	7.71	4.656	11
		Total	6.79	4.057	22
Shows tension	1	No	3.70	1.290	5
		Yes	8.16	2.565	5
		Total	5.93	3.033	10
	2	No	5.56	4.440	6
		Yes	13.16	10.561	6
		Total	9.36	8.683	12
	Total	No	4.71	3.387	11
		Yes	10.89	8.076	11
		Total	7.80	6.819	22
Shows antagonism	1	No	24.73	14.334	5
		Yes	43.73	19.966	5
		Total	34.23	19.203	10
	2	No	17.20	13.200	6
		Yes	25.24	13.821	6
		Total	21.22	13.552	12
	Total	No	20.62	13.593	11
		Yes	33.64	18.659	11
		Total	27.13	17.268	22

A Multivariate Analysis of Variance was conducted to evaluate the relationship between the number of controllers, gestures and the type of interaction seen within groups.

The number of controllers and their use without and with gestures were the independent variables and Bales' twelve interaction constructs were the dependant variables.

There was a main effect of number of controllers on the 'solidarity interaction' construct, $F(1, 18)=12.80$, $p=.002$ with a higher number of interactions of this type when dyads had one-controller ($M=14.45$, $SD=6.64$) than two-controllers ($M=6.29$, $SD=5.09$).

There was also a main effect of number of controllers on the ‘gives orientation’ construct, F(1,18)=24.26, p=.000 with a higher number of interactions of this type when dyads had one-controller (M=82.18, SD=22.58) than two-controllers (M=41.52, SD=19.49).

There was also a significant main effect of number of controllers on the ‘gives opinion’ interaction construct, F(1,18)=7.71, p=0.12 with a higher number of interactions of this type when dyads had one-controller (M=32.50, SD=13.23) than two-controllers (M=18.53, SD=9.87).

There were no other significant main effects with regards to the controller configuration and type of interaction construct as proposed by Bales’ Interaction Process Analysis.

In consideration of the influence of the without and with gestures factor the Multivariate Analysis of Variance indicated:

A significant main effect of gestures for the solidarity interaction construct, F(1,18)=5.24, p=0.34 with a higher number of interactions of this type with gestures (M=12.98, SD=7.60) than without (M=7.76, SD=5.73).

A significant main effect of gestures was also true for the tension release construct, F(1,18)=8.27, p=0.10 with a higher number of interactions of this type with gestures (M=51.02, SD=21.46) than without (M=30.40, SD=12.81).

There was also a significant main effect of gestures for the gives orientation interaction construct, F(1,18)=4.96, p=0.39 with a greater number of interactions of this type occurring with gestures (M=71.04, SD=30.18) than without (M=52.66, SD=26.38).

Finally, there was a significant main effect of gestures for the shows tension interaction construct, F(1,18)=5.18, p=0.35 with a higher number of interactions of this type with gestures (M=10.66, SD=19.97) than without (M=4.63, SD=14.33).

6.3.3. The influence of prior experience factors on the type of interaction

Analysis of variance was completed for all of the pre-test measures outlined at the beginning of this Chapter. The independent variables were the category of interaction as well as the number of controllers and their use with and without gestures and the dependent variable was the pre-test variable to be applied. These findings are now presented here:

(1) An Analysis of Variance indicated that there was no significant main effect of prior experience of concept mapping on the categories of interaction, $F(1,16)=4.371$, $p=0.053$, with groups with experience displaying more interactions ($M= 8.41$) than those groups with no prior experience of concept mapping ($M= 6.18$). There were no interaction effects.

(2) An Analysis of Variance indicated that there was no significant main effect of prior WiiRemote usage on the type of interaction for either condition. There were also no interaction effects.

(3) An Analysis of Variance indicated that there was a significant main effect of perceived skill at gesturing on the type of interaction for:

a) <u>Shows solidarity</u>: $F(2,14)= 5.014$, $p= 0.023$ novice, ($M= 6.23$), novice/experienced, ($M= 15.63$) experienced ($M= 9.87$);
b) <u>Gives opinion</u>: $F(2,14)= 4.536$, $p= 0.030$ novice, ($M= 79.28$), novice/experienced, ($M= 100.67$) experienced ($M= 126.37$);
c) <u>Gives orientation:</u> $F(2,14)= 9.159$, $p= 0.003$ novice, ($M= 60.91$), novice/experienced, ($M= 79.06$) experienced ($M= 55.87$).

There was also an interaction effect of gestures without and with them enabled for the 'gives orientation' effect and perceived skill at gesturing $F(2,14)=5.273$, $p=0.020$. There were no other interaction effects.

(4) An Analysis of Variance indicated that there was a significant main effect of *group year* on the type of interaction for:

a) Shows solidarity: $F(2,12)= 5.055$, $p= 0.026$; year 1, (M= 15.32), year2, (M= 8.99) and year 3 (M= 9.7).
b) Gives suggestion: $F(2,12)= 12.065$, $p= 0.001$ year 1, (M= 40.64), year2, (M= 19.69) and year 3 (M= 21.41);
c) Shows antagonism: $F(2,12)= 8.642$, $p= 0.005$; year 1, (M= 43.89), year2, (M= 20.11) and year 3 (M= 24.68).

There was also an interaction effect of controllers for the 'gives suggestion' effect and the year group, $F(1,14)=7.726$, $p=0.017$. There were no other interaction effects.

(5) An Analysis of Variance indicated that there was a significant main effect of handedness on the type of interaction for the 'shows solidarity' interaction category, $F(1,14)=5.071$, $p=0.041$ with mixed handed groups having a higher number of interactions of this type (M=12.725) than both right handed groups (M= 6.930). There were no interaction effects.

(6) An Analysis of Variance indicated that there was a significant main effect of prior usage of other gesture-orientated technology upon the type of interaction for:

a) Gives suggestion: $F(3,10)=7.673$, $p=0.006$, both no (M= 23.80), mixed experience (M= 54.86), both yes (M= 19.50);
b) Shows antagonism: $F(3,10)=5.412$, $p=0.018$, both no (M= 19.90), mixed experience (M= 61.97), both yes (M= 27.96);

There were no interaction effects.

(7) An Analysis of Variance indicated that there was a significant main effect of frequency of use of WiiRemote controllers on the type of interaction for:

a) Shows solidarity: F(3,10)=4.880, p=0.024, weekly (M= 23.73), monthly, (M= 9.07) weekly/monthly (M= 8.14);
b) Shows tension release: F(3,10)=4.718, p=0.027 weekly (M= 57.36), monthly, (M= 32.12) weekly/monthly (M= 50.55);
c) Gives suggestion: F(3,10)=14.530, p=0.001 weekly (M= 54.86), monthly, (M= 23.96), weekly/monthly (M= 17.27);
d) Gives orientation: F(3,10)=10.991, p=0.002 weekly (M= 83.81), monthly, (M= 57.02) weekly/monthly (M= 63.19);
e) Shows tension: F(3,10)=10.770, p=0.002 weekly (M= 7.10), monthly, (M= 5.93) weekly/monthly (M= 7.29);

There was also an interaction effect of gestures for the following categories:

a) Gives suggestion: F(3,10)=3.930, p=0.043 without gestures (M= 25.36), with gestures, (M= 28.10).
b) Shows tension: F(3,10)=4.735, p=0.026 without gestures (M= 4.86), with gestures, (M= 13.65).
c) Tension release: F(3,10)=3.805, p=0.047 without gestures (M= 31.31), with gestures, (M= 58.86).

There were no other interaction effects.

6.3.4 Summary of types of interaction

There was a significant effect of controller usage and the amount of interactions that occurred for the 'shows solidarity', 'gives orientation' and 'gives opinion' categories. At the same time there was also a significant effect of gesture usage for the 'shows solidarity', 'tension release', 'gives orientation' and 'shows tension' interaction categories.

Significance was also found with regards to perceived skill at gesturing for the shows solidarity, gives opinion, gives orientation and asks for orientation categories. Further significance could also be seen by group year, handedness, prior usage of other gesture-based technology, and prior frequency of use of controllers for certain categories of interactions.

6.4 Impression formation and social dominance

Having described the social dominance constructs in section 6.2.8 of this Chapter the group scores for each of the social dominance constructs were analysed in relation to the total amount of interaction for each group. The analysis considers the conversational construct first, followed by the influence and poise construct and finally the self assurance construct is considered for controller usage and then gesture usage. The analysis of these constructs then considers the type of interaction that was displayed for the conversational control construct only as no significance was found for the influence and poise construct or the self assurance construct. However, the descriptive statistics for the amount of interaction is recorded for all of the remaining social dominance constructs.

6.4.1 Conversational control and amount of interaction

The descriptive statistics for the mean total number of interactions for each controller condition was reported with regards to the group conversational control score and are presented in Table 6.8.

Table: 6.8 Group conversational score by controller number and the mean total number of interactions.

Dependent Variable	Controllers	Conversational Control Group Score (High/Low)	Mean	SD
Total interaction	1	Both low	388.040	68
		Mixed	492.802	109
		Both high	394.871	107
	2	Both low	233.008	64
		Mixed	198.407	70
		Both high	399.071	140

An Analysis of Variance was conducted for each of the three social dominance constructs to evaluate their relationship to the total number of interactions that occurred when using varying numbers of controllers. The total number of interactions was the dependent variable, and the number of controllers and the level of the social dominance construct (high or low) were the independent variables between subjects for each construct.

There was a main effect of number of controllers, which has already been reported in section 6.3.1.1.

There was no main effect of conversational control and the total number of interactions.

There were no other interaction effects.

The descriptive statistics for the mean total number of interactions for use of the controller(s) without and with gestures enabled and the influence of conversational control are presented in Table 6.9.

Table: 6.9 Group conversational score with and without gestures and the mean total number of interactions.

Dependent Variable	Gestures	CC Score HI/LO	Mean	SD
Total interaction	No	Both low	275.568	75
		Mixed	280.404	198
		Both high	334.760	129
	Yes	Both low	345.479	126
		Mixed	410.806	176
		Both high	459.182	32

There was a main effect of gestures which has already been reported in section 6.3.1.2.

Main effects of conversational control and the total number of interactions were not significant.

There was no interaction effect of conversational control and gestures and the total amount of interaction.

There were no other interaction effects.

6.4.3 Influence and poise and amount of interaction

Due to the lack of variance in the scoring of this construct (see Table 6.10) no statistical significance was observed for either controllers without or with gestures. This is also true of the type of interaction and, therefore, there was no statistical significance reported there either.

The descriptive statistics for the mean total number of interactions and this construct are shown for controller usage and are presented in Table 6.11. This suggests that those pairs with mixed influence and poise scores have higher levels of interaction when using one-controller (M=457.88, SD=105) than compared with two-controllers (M=310.27, SD=141) and that mixed scores in the one-controller condition (M=457.88, SD =105) have higher levels of interaction that those with both high scores (M=394.87, SD= 70).

The mean total number of interactions without and with gestures are shown in Table 6.12.

Table: 6.10 Number of occurrences (N) of the influence and poise social dominance construct

	Influence and poise group score	# of responses
Influence and poise group score(High/Low)	Mixed	18
	Both high	4

Table: 6.11 Group influence and poise score by controller number and the mean total number of interactions.

Dependent Variable	Controllers	Influence and poise group score	Mean	SD
Total interaction	1	Mixed	457.88	105
		Both high	394.87	70
	2	Mixed	310.27	141
		Both high	-	-

Table: 6.12 Group influence and poise score with and without gestures and the mean total number of interactions.

Dependent Variable	Gestures	Influence and poise group score	Mean	SD
Total interaction	No	Mixed	328.02	142
		Both high	349.95	70
	Yes	Mixed	440.14	133
		Both high	439.79	43

6.4.4 Self assurance and amount of interaction

The descriptive statistics for the mean total number of interactions and this construct are shown for controller usage and are presented in Table 6.13. The mean total number of interactions without and with gestures are shown in Table 6.14.

Table: 6.13 Group self assurance score by controller number and the mean total number of interactions.

Dependent Variable	Controllers	Self assurance group score (High/low)	Mean	SD
Total interaction	1	Both low	569.65	77
		Mixed	401.90	65
		Both high	388.04	68
	2	Both low	.	.
		Mixed	312.00	145
		Both high	306.81	154

Table 6.14 suggests that when using one-controller, pairs with both low scores in relation to self assurance have higher levels of interaction (M=569.65, SD=77) than pairs with both high self assurance scores (M=388.04, SD= 68).

With regards to the total interaction and the without and with gestures factor both low level self assurance scores resulted in higher levels of interaction (M= 514.96) and (M=624.34) when compared to both high self assurance scores for the non use of gestures and the use of gestures (M=266.56, SD=125) and (M=401.21, SD=114).

Table: 6.14 Group self assurance score with and without gestures and the mean total number of interactions.

Dependent Variable	Gestures	Self assurance group score	Mean	SD
Total interaction	No	Both low	514.96	.
		Mixed	300.70	122
		Both high	266.56	125
	Yes	Both low	624.34	.
		Mixed	400.36	110
		Both high	401.21	114

6.4.5 Conversational control and types of interaction

There was a significant main effect of group conversational control score on the ‘gives orientation’ construct, F(2,10)=4.63, p=.038 with a higher number of interactions for low, mixed and high scores of this type when dyads worked with one-controller as opposed to two-controllers (see Table 6.15).

Table: 6.15 Effect of conversational control on the number of interactions by controller configuration for the gives orientation construct.

Controllers	Conversational control group score	Mean	SD
1	Both low	69	38
	Mixed	81	20
	Both high	90	22
2	Both low	26	3
	Mixed	30	17
	Both high	56	17

There was a significant interaction effect of group conversational control score on the ‘shows solidarity’ construct, $F(2,10)=4.86$, $p=.034$ with a higher number of interactions for low, mixed and high scores of this type when dyads worked with one-controller as opposed to two-controllers (see Table 6.16).

Table: 6.16 Effect of conversational control on the number of interactions by controller configuration for the shows solidarity construct.

Controllers	Conversational control group score	Mean	SD
1	Both low	13	6
	Mixed	18	8
	Both high	11	4.5
2	Both low	4	3
	Mixed	1	1.5
	Both high	10	4.5

There were no other interaction effects.

6.5 Group process and outcome

6.5.1 Controller possession (one-controller condition only).

Birnholtz et al. [2007] hypothesised that in a single controller condition a user who initially made use of the controller would use that controller for a greater amount of time. With this initial assertion through initial control of controller this could then affect the perceived social dominance of that user (although they found little evidence to support this for a negotiation task). This hypothesis was also explored here in the context of conceptual maps, whereby the time the controller was in the possession of each participant and the number of controller handovers was recorded. As a further extension to this hypothesis in the context of this experiment it was also expected that more exchanges of controller would occur in the with gesture condition as opposed to the without gesture condition.

An Analysis of Variance was conducted to determine the relationship of initial control of the controller on the amount of time the controller was in possession. The descriptive statistics are summarised in Table 6.17. When the controller is initially picked up, the participant who did so controlled the controller for longer (M=19.47, SD=5.53) than those participants who did not initially pick up the controller (M=7.98, SD=3.62). This was statistically significant, $F(1,20)=30.29$, $p<0.001$.

Table 6.17: Mean time spent in control of the controller when first picked up.

Initially in control	#	Mean	SD
No	10	7.98	3.62
Yes	10	19.47	5.53
Total	20	13.73	7.45

To determine if this disproportionate amount of control due to initial controller pick up affected the self-perceived social dominance of the participant, an Analysis of Variance was carried out, whereby the independent variable was the first person in possession of the controller, and the dependent variables were the social dominance constructs: conversational control, influence and poise and self-assurance.

The results of the ANOVA for the social dominance constructs are summarised in Table 6.18. There was a significant effect of this factor on the influence and poise displayed by the participants, F(1,20)=4.430, p=0.05.

Table 6.18: Significance for the ANOVA of social dominance constructs for initial possession of controller

		F	Sig.
Conversational control	Between groups	0.092	0.765
	Within groups		
	Total		
Influence and Poise	Between Groups	4.430	0.050
	Within Groups		
	Total		
Self Assurance	Between Groups	0.062	0.806
	Within Groups		
	Total		

A further correlation comparison was then applied to see if there was a significant correlation between the amount of time in possession of the controller with the social dominance construct scores. Table 6.19 summarises these results. There were no significant correlations.

Table 6.19: Correlations between the amount of time in possession of the controller and social dominance constructs

			Conversational control	Influence and poise	Self assurance
Conversational Control	Pearson Correlation	0.056			
	Sig. (2-tailed)	0.814			
Influence and Poise	Pearson Correlation	0.247	0.265		
	Sig. (2-tailed)	0.295	0.082		
Self Assurance	Pearson Correlation	-0.090	-0.181	0.068	
	Sig. (2-tailed)	0.705	0.239	0.662	

N =20

With regards to the number of controller hand-overs the mean number of handovers by non/use of gestures is summarised in Figure 6.2.

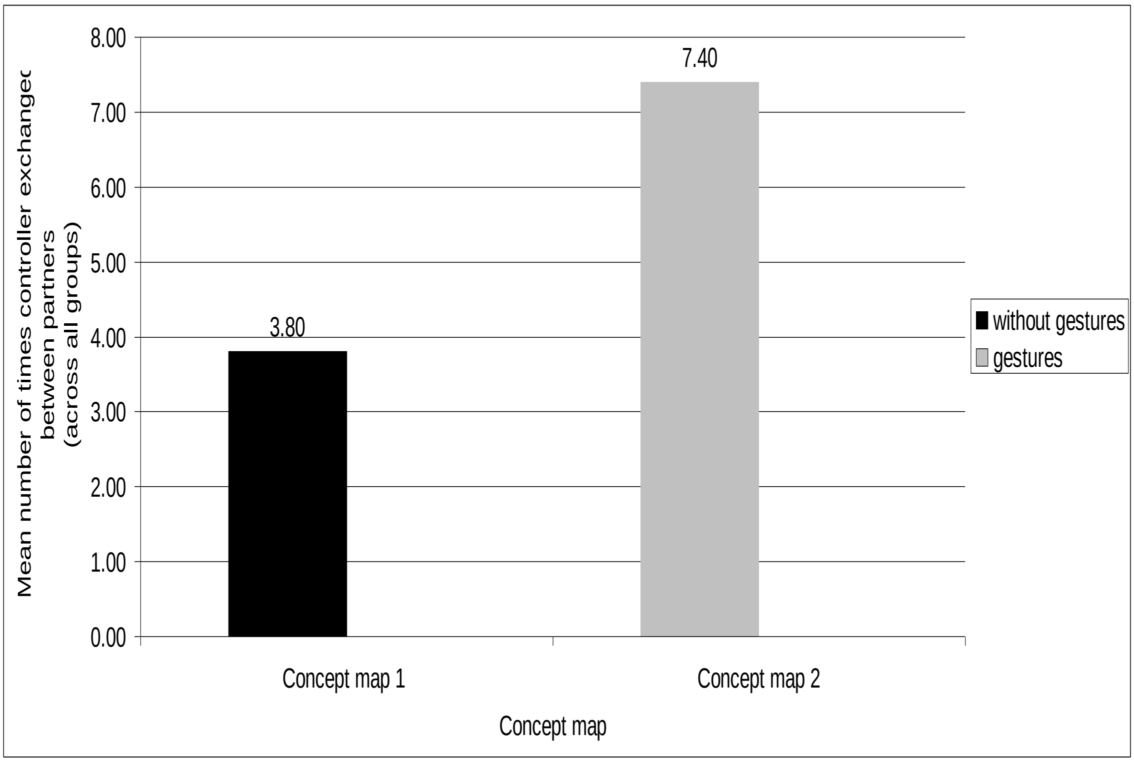


Figure: 6.2 Mean handovers by gesture configuration.

The number of controller hand-overs in the with gestures condition is higher when compared with the without gestures condition. From observation this was generally because once in possession of the controller without gestures the participant, who was familiar with devices in this format, did not want to give up the possession of the controller. However, when the controller was used with gestures the inability at some points to create gestures or the correct gesture meant that the controller was more likely to be handed over because of these failures. S13 and S14 (information taken from the video transcript) for example highlight this by changing possession of the controller twice in the first 52 seconds of the with gestures condition and one controller only experiment:

> S13:Cool right {in possession of the controller).
> S13:Can't I just... Your go! {Passes the controller to 2}.
> S14:Ah Yes! {successfully does gesture} {Smiles smugly at partner who looks back}.
> S14:I can't do it. Is that the one in the first year?
> S14: Can't do it at all.
> S13:Do you want me to try? {1 now in possession of the controller}.

These extracts shows competitive behaviour displayed when being able to create gestures when the other participant could not complete the gesture. It also shows a willingness to work as a team when gesture recognition impacts upon their ability to work together as a group. This is just one example of a number of role assignments that exist.

For example, in the one controller condition the controller was not allocated to an individual participant. The strategies as to who would take up initial control of the controller varied. Video analysis showed that people assigned this role either implicitly or explicitly.

For example first use of the controller was often negotiated:

Experiment 1:

S1: Who wants the controller first?

S2: You can have it first I think, go for it

S1: Fair enough

Experiment 2:

S1:Here (Offers controller).

S2:Shakes head.

S1: Do you want to? (in possession of the controller).

S2: You can open up the system this time? {Laughter}

At the same time however, whilst there was often initial negotiation with regards to the use of one controller with no gestures there were instances in the one controller with gestures condition where this initial negotiation was replaced by one user deciding that they wanted to take control of the controller without any negotiation.

Experiment 1:

S7:Do you want first go?

S8: You can go first

S7: So we're starting with computer systems I reckon... Can you see that ok?

Experiment 2:

S7:How do we start it?

S7: {Makes Gesture} Oh that one.

S8: Ah let's have a go {denied by partner}

It might therefore be a possibility that gestures, at least, initially could cause conflict with regards to their initial possession, perhaps due to their novelty as a medium of input.

Some groups also adapted their role assignment depending on their perceived ability of each other which in the main was consensual although some participants had their role forced upon them by the other member, or withdrew from the process of creating the concept map through self recognition of their deficiencies when gesturing. The latter withdrawal and dominance of individuals with poor-self perceived gesturing-capability when compared to their partner appeared to occur more regularly in the one controller condition with the gestures enabled. In some groups, the controller was used 'baton' like between individuals where one participant was deemed by the group to be better at typing and would input the words and the other might be deemed better at gesturing and take possession of the controller at these points. This method of behaving was also repeated in the two controller condition, even when the participants had a controller each. Members of the group in the two controller condition would use one controller for adding words and one controller for creating nodes and structural design.

Often in the two controller condition with gestures, the user with better group perceived gesturing capability created the nodes. Therefore in some cases the role assignment when concept mapping was aligned to strengths and weaknesses and in some case withdrawal when a participant could not master the gestures as well as say their partner. In this case, rather than having a controller each and empowering them through having a controller each, it only served to highlight the deficiencies of one person when gesturing which was further confirmed in the semi structured interviews:

> S7: We were about equal both times, but he manages to get a grip on some of the gestures better which sped him up on the second task
>
> Interviewer: How did that make you feel?
>
> S7: Hurt (cry smiley). It really it did both me bother.

Crucially participant (S7) felt disempowered by the use of gestures as he felt he was not as proficient as his partner.

6.5.2 Influence on task

It was hypothesised that more leaders would be present in the one-controller condition as opposed to the two-controller condition due to the expected initial control of the controller. More dominant users would be more likely to pick up the controller and, therefore, wish to take control of the controller as seen in section 6.5.1. Such individuals might then consider themselves to be leaders and, therefore, it was expected that more leaders would be present in one-controller groups.

The mid and post-experiment questionnaire asked participants if their partner, themselves or nobody had emerged as a group leader, with this measure and the subsequent measures discussed here initially discussed in section 5.4.2 of this thesis. More participants reported that a leader emerged in the two-controller condition (11) than in the single controller condition (9). Of these 9, (5) rated themselves the leader and (4) rated their partner as leader for the one-controller condition. For the two-controller condition (6) of the 11 rated themselves the leader and the remainder thought their partner was the leader.

With regards to the use and non use of gestures more participants in the two-controller condition (4 participants) rated themselves as leader as opposed to (2) without gestures and (1) participant rated their partner as leader as opposed to (4) without gestures. In the single controller condition more participants rated themselves as leader without gestures (3) as opposed to (2), with this pattern also followed when rating a partner as leader (3) without gestures, (1) with gestures. See Figure 6.3 which provides a summary of the frequencies of response.

To explore whether there was a relationship between the number of controllers (with and without gestures) on perceived levels of group influence a chi square test was conducted. The test indicated that there was no significance between perceptions of leadership and the use of one or two-controllers with or without gestures.

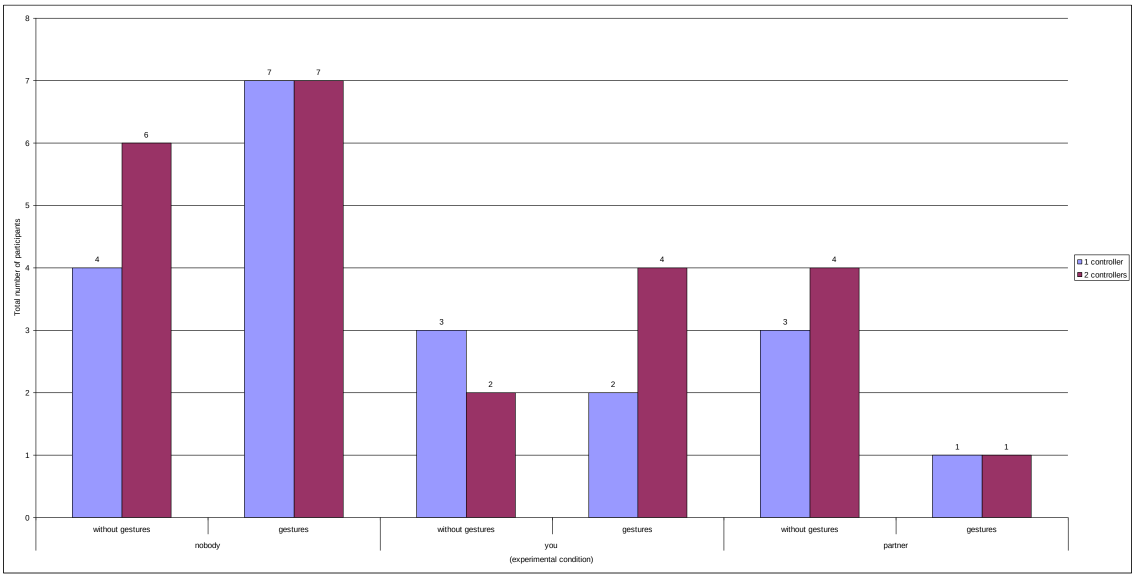


Figure: 6.3 Frequency of number of participants who stated that nobody, themselves or their partner emerged as leader.

6.5.3 Perceived contribution

It was hypothesised that when using gestures as opposed to no gestures individuals within groups would rate their partner higher than themselves for gesture usage as they might be less confident of their abilities in these areas. However, in the single controller condition groups would rate themselves as having contributed the most to the concept mapping process.

The participants were asked to assess their partner's contribution to the concept map with regards to the perceived percentage amount they influenced the final solution. The mean contributory scores for all groups by condition are summarised in Figure 6.4.

The mean percentage score for one-controller without gestures was 49%; this figure did not change for the one-controller group when using gestures. With regards to the two-controller condition; the condition without gestures indicated a mean contributory score of their partner of 52%, rising to 56% when using gestures with two-controllers. As such, single controller participants rated their own influence as being slightly higher than that of their partner (51% (self) ~49% (partner)), with those in the two-controller option rating their partner's influence as being higher than their own for without gestures (52% (partner) ~48%(self)) and with gestures (56% (partner) ~44%(self)). This was not a significant difference.

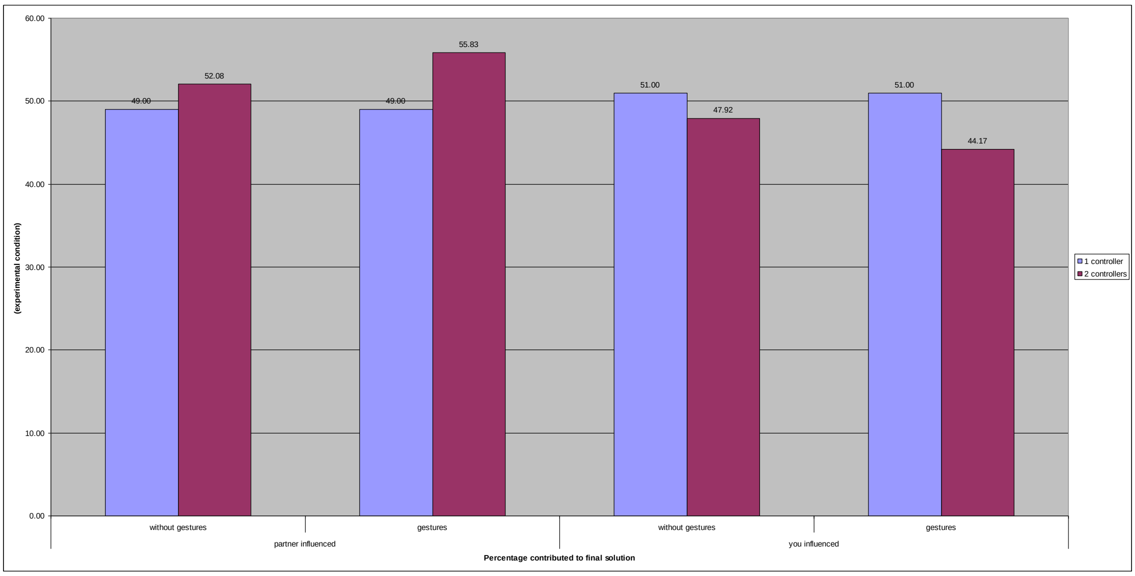


Figure: 6.4 Percentage contributions of partner and subsequently themselves to completing the tasks.

When describing their contributions the participants inadvertently described their collaboration strategy. For example, when explaining his contribution one student described collaborative learning when using two controllers as two users working independently on different sections of the concept map:

> S1: The great thing about the program is that it can be used by multiple people, which allows you to work on the diagram together - I found that I could work on one half of the map, whilst my partner worked on the other. As a team, we kept up a bit of conversation about the map as we worked, so rather than work on each half separately, we commented on the others half, and made suggestions as to how we would link them. So yes, I think we did work effectively as a team. In terms of contribution, I think it was evenly split between my partner and I - both of us made comments about the map the other was creating, and made decisions about our own maps.

At the same time, other group strategies involved ownership of particular roles such as structuring the concept map:

> S5: I think that I contributed quite a bit, as I tend to like to take control on computer related activities. Probably more so than my partner. Normally by using the ideas which I thought of for the concept maps, especially starting them off, so yeah I did more of the structuring of the maps. I did less so of the actual using of the remote, I think.

It is interesting that S5 thought that they dominated their partner, as S6 did not see this as being the case. So within groups there is some discrepancy between how the group members perceive themselves to be working together:

> S6: Well we were both working on the same things, after a small discussion on what we need to do. this happened in both conditions. Yeah I thought we worked well together, no-one dominated, just got on with the job together.

At the same time other group members in the two controller condition consider themselves to excel at some areas i.e. typing but not gesturing and take pride from their ability to do something that their partner could not, when they thought they were not as good at gesturing as their partner:

> S8: I can fairly say I've contributed my share. Although when it came to the second map XXXX did a lot more of the manual work. I was having a hard time with gestures. Although I did most of the typing because he had a hard time with that. When I was having a hard time doing something or remembering something, he would step up and do the work and vice versa.

Whilst some participants thought that they were dominating others, other group members realised that they were being marginalised by their inability to gesture as represented by student (S7) described earlier in this chapter.

When only having one controller however the collaboration strategy was affected in terms of who had possession of the controller at the time. If a participant was in possession of the controller then they tended to drive the construction of the concept map and its structure, whereas the person not in possession of the controller was in charge of providing content, with this role changing vice versa depending on who was in control of the controller (as found by Birnholtz et al. [2007]):

> S9: We specialised when we could, and divided the work fairly well

In some cases however, there was not this interchange of roles:

> S3: I think we could've been more effective, because we were simply watching the other person do the pointing and stuff when we didn't have the remote. What discouraged me was probably not getting the gesture the first time in the first situation and not being able to point more accurately in the second situation I guess.

With most participants willing to give up use of the controller when asked:

> S10: I'd say he contributed the same, and I asked for the controller a couple times and he gave it up straight away, so there wasn't any conflict, he just had a preference for it and I didn't. When we tried to do something we got it done, but as a team we weren't particularly geared to completing the task itself

Again the strategies for completing the tasks were varied with individual participants assuming particular roles:

> <u>Two Controllers.</u>
> S1: Well, I seemed quite focused on the design of the map - how it looked on the screen, rather than its function. Other than that, though, both my partner and I concentrated more of the basic skeleton - what our main nodes were going to be, what they should be called, and what the links between them should be. We managed to get as far as the two main modules (Csys and Csys II, and the IP ones), and the sub-modules contained within them, but we didn't delve into what we got from each sub-module, and how the things we learnt in a particular sub-module were connected.
>
> S5: I'd probably say the module content. I was pretty content with the role I had yes.

S6: We seemed just to go through logically, e.g. course title, what's under that, the lecturer, the room. We could say titles and the key elements however we didn't actually say what we had specifically learnt.

S8: We took a very incremental approach thinking of new things as we finished each stage.

<u>One Controller.</u>

S3: We filled the gaps that the other person had it was interesting to see how much I'd actually forgotten, as well as seeing how much we'd done.

S4: I think I concentrated on trying to generate more elements to put in the map. This was simply because I thought more elements would be more useful than trying to organise the ones we already had.

S9: I think we focused on module content, presenting a rough overview of what can be expected to be taught, skills could be implied from that, but not really prereq's no. We focused on these more because they were easiest and clearest to lay out. Plus we hadn't really looked at next year's work so we couldn't comment on prereq's and how they relate too much.

S10: We focused most on modular concept, because I barely know what key skills or knowledge prerequisites mean in context.

6.5.4 Agreement

It was hypothesised that when using gestures as opposed to no gestures individuals within groups would disagree with the final outcome of the concept more when using gestures as opposed to the non use of gestures.

The participants were asked to complete a series of Likert scale measures to assess the extent to which they agreed with the final concept map for each of the controller configurations. The Likert scale used was a 7-point scale with lower scale of 1 being a negative response and 7 being a positive response (see Appendix 7 for the questions asked for this measure). The mean scores for all groups that used one-controller with and without gestures and who used two-controllers with and without gestures is summarised in figure 6.5.

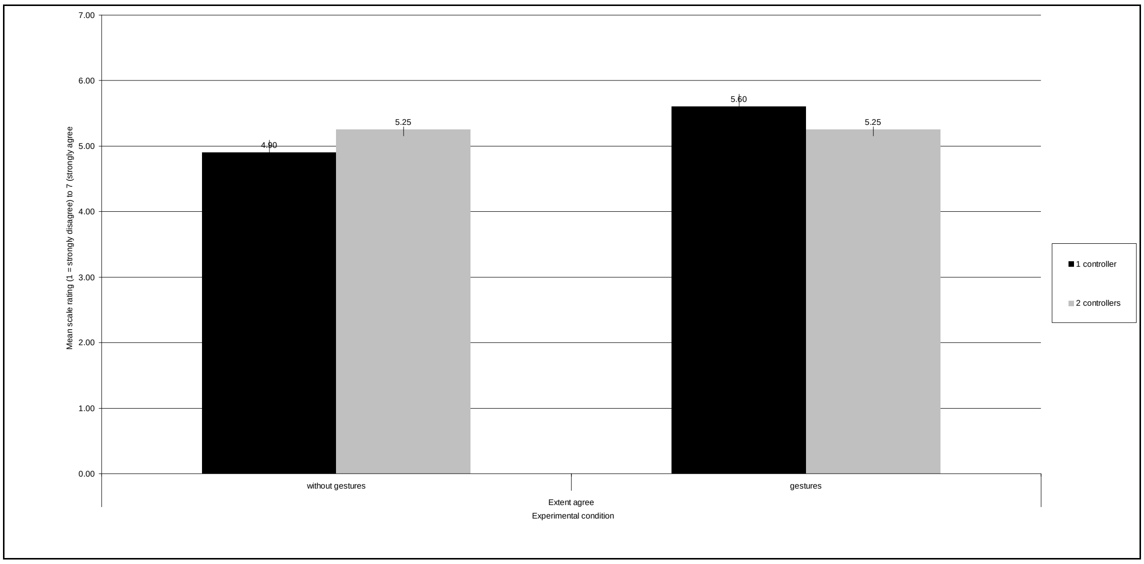


Figure: 6.5 Average rating score for agreement with the final solution to the concept maps.

There was no difference in the amount of agreement for all groups when using the two-controller condition (M = 5.25, SD = 1.60 without gestures, M = 5.25, SD = 1.38), however, the overall extent to which groups agreed with the final solution to the concept map for one-controller without and with gestures differed: (M = 4.90, SD = 1.20 without gestures ~ M = 5.60, SD = 1.07 with gestures). Therefore, there was more disagreement with gestures than without gestures in the one-controller condition and there was no difference between the two for two-controllers irrespective of gesture usage. To explore whether there was any statistical significance in relation to these differences described with regards to the use of gestures and one and two-controllers and the level of agreement for the completion of the concept maps, the scores were combined. A Univariate Analysis of Variance was then completed, with the agreement measure as the dependent variable and the number and configuration of controllers as the independent variables. The ANOVA indicated that there was no significant influence of controllers and gestures on levels of agreement with the final concept maps.

6.5.5 Group discussion

The participants were asked to complete a series of Likert scale measures to assess the quality, effectiveness and orderliness of the group discussion as well as the overall satisfaction with the outcome. The Likert scale used was a 7-point scale with one the lower scale of 1 being a negative response and 7 being a positive response (see Appendix 8 for this measure).

The mean rating scores for each measure, i.e. overall satisfaction for one and two-controller usage and without and with gestures are summarised in Figure 6.6.

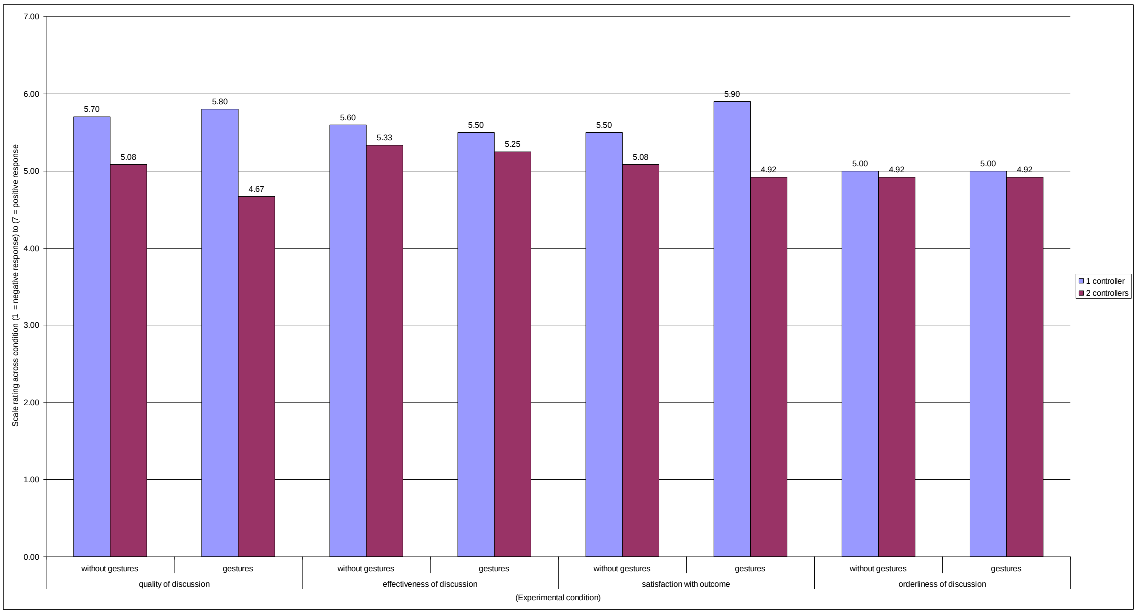


Figure: 6.6 Average rating score for quality of discussion, effectiveness of discussion, satisfaction with outcome and orderliness of discussion for conditions.

An Analysis of Variance was conducted with the discussion measure being the dependent variable, and the number of controllers and the use of gestures the independent variables.

In consideration of the influence of the one or two-controllers factor the Multivariate Analysis of Variance indicated:

A significant main effect of number of controllers occurred for the quality of discussion, $F(1,40)=7.719$, $p=0.008$ with a higher mean rating achieved with one-controller (M=5.75, SD=1) than with two-controllers (M=4.875, SD=1.22).

A significant main effect of number of controllers occurred for the satisfaction with outcome measure, $F(1,40)=5.450$, $p=0.025$ with a higher mean rating achieved with one-controller (M=5.7, SD=0.98) than with two-controllers (M=5.0, SD=1.09).

There were no other main effects for the independent variables.

There were no interaction effects.

6.5.6 Summary

When the controller is initially picked up, the participant who did so controlled the controller for longer than those participants who did not initially pick up the controller. There was also a significant effect of initial control of the controller on the influence and poise displayed by the group participants. More controller handovers between participants occurred in the with-gestures condition.

There was no significance between perceptions of leadership and the use of one or two-controllers with or without gestures. Single controller participants rated their own influence as being slightly higher than that of their partner (51% (self)~49% (partner)), with those in the two-controller option rating their partner's influence as being higher than their own for without-gestures (52% (partner)~48%(self)) and with-gestures (56% (partner)~44%(self)), but again this was not significant.

There was also no significant influence of controllers and gestures on levels of agreement with the final concept maps. Additionally, higher levels of satisfaction with group discussion were displayed for one-controller usage, which was also true for the satisfaction with the final outcome. This, when considered with the increased amount of interaction found for one-controller, suggests that there is some evidence that as well as increased levels of interaction, one-controller affords higher self-perceived levels of quality of discussion.

6.6 Amount and type of interaction and their relation to the concept mapping process and product

During the concept mapping tasks, participants were asked to construct a series of concept maps which considered the module content, their understanding of what they had learnt from their modules, and what they expected to learn, as well as their understanding of the key skills that they felt they had acquired from the modules that they had studied. Three dimensions of their conceptual maps were assessed; the number of nodes, the number of edges (as an end product measure), and the number of words created (including those words that were deleted as part of the construction process of the concept map). These constructs, therefore, constitute the process and the end product of the concept mapping processes. They do not form an accurate indicator of any learning and are not interpreted in this way throughout the thesis.

H4: It was hypothesised that:

- *Individuals would create more nodes, and subsequently words and edges, in the one-controller condition than the two-controller condition, with gesture usage eliciting more nodes, words and edges than without gesture usage.*

Correlations between the total number of interactions, the number of edges, conceptual nodes and total number of words were calculated to determine the relationships between these measures. It was assumed that the number of edges and nodes would be highly correlated and that those who interacted more might create more nodes, edges and words. The correlations are displayed in Table 6.20. The correlations between these measures were not significant and, therefore, do not require any further analysis.

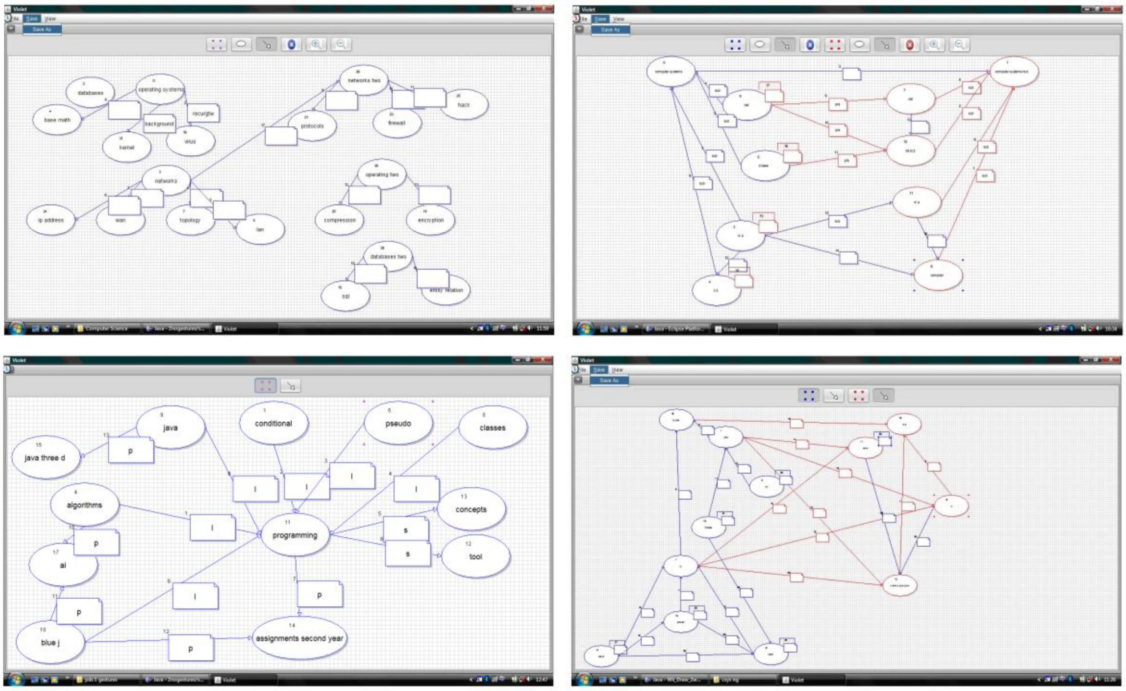
Table: 6.20 Correlations between the total amount of interaction and the total edges, words and nodes created.

	Total number of interactions	Edges	Words
Edges	0.02		
Words	0.14	0.34	
Nodes	0.13	0.70**	0.27

** Correlation is significant at the 0.01 level (2-tailed).
N = 22

Figure 6.7 shows some examples of the concept maps created for the one and two-controller condition without and with the use of gestures.

1 controller without gestures　　2 controllers without gestures



1 controller with gestures　　2 controllers with gestures

Figure 6.7 Example concept maps created by experimental condition.

The means of the total number of nodes, words and edges for one and two-controllers with and without gestures are summarised in Figure 6.8.

The means of the number of nodes, number of words and number of edges are very similar for both one and two-controllers whether with or without gestures. There is no significant difference in relation to the number of nodes that are constructed for the between groups factor of controller without gestures with one-controller without gestures node construction (M=14) and two-controllers node construction (M=9).

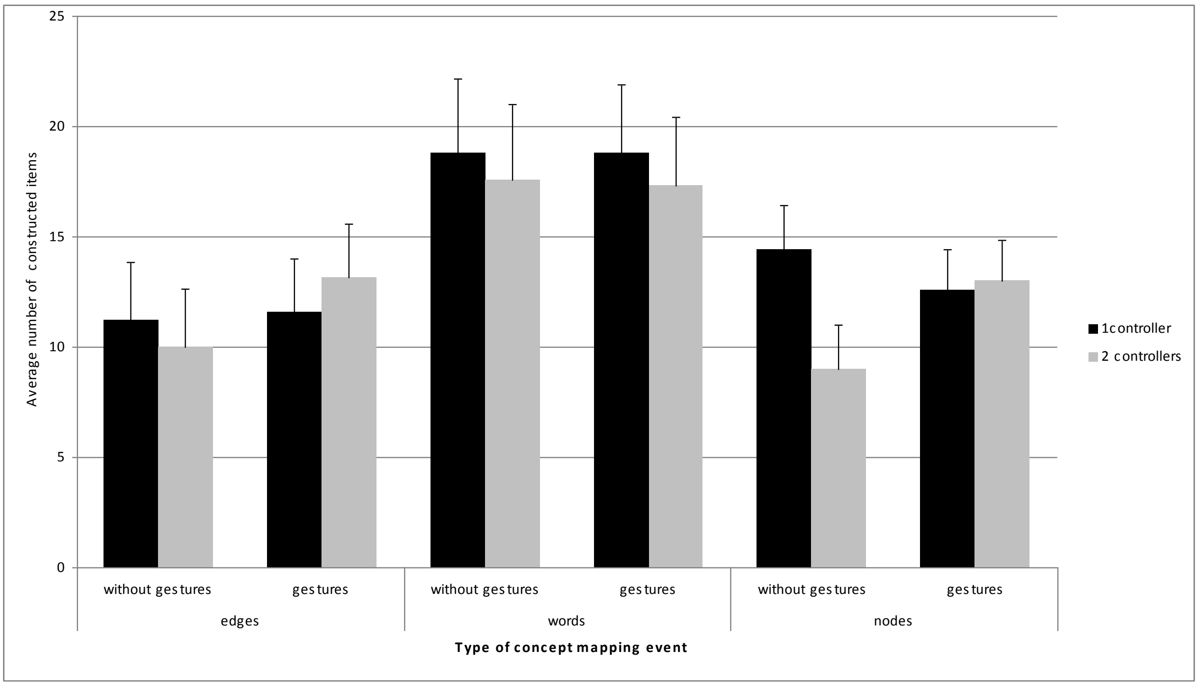


Figure 6.8 Group means for the construction of edges, words and nodes.

To understand the relationship between the number of nodes created in relation to the total number of interactions expressed, a group score was applied to the number of nodes constructed. A median split was applied to find the median of the number of nodes constructed. A score of >12 nodes was determined to be a high score based on a median split of the total number of nodes created for each pair. A score of 12 nodes or less was classified as being low. Logically orientated problems exist when using median splits, where any categorisation above the median is considered equal. This is also true of values just below the median i.e. is 11 really that much different from 12? One solution might be to split the sample further into three groups instead of perhaps two. This creates some separation between the two groups, however the obvious problem here is that a third of the sample is then lost. In this case, to lose a third of the sample would have reduced the power of any comparisons.

Following the median split, a one-way Analysis of Variance was conducted to evaluate the relationship between the number of nodes created and the total number of interactions that occurred. The ANOVA indicated that there was no main effects of high or low node construction on the total number of interactions as a between groups factor. The descriptive statistics are shown in Table (6.21)

Table: 6.21 Descriptive statistics for number of nodes created and total number of interactions.

Controllers	Gestures	Node high/low	Mean	Std. Deviation
1	No	low	427.62	123.52
		high	353.73	49.60
		Total	383.29	81.74
	Yes	low	453.09	24.46
		high	501.38	110.82
		Total	482.07	83.61
	Total	low	440.36	74.17
		high	427.56	111.52
		Total	432.68	93.74
2	no	low	273.02	140.47
		high	137.98	.
		Total	250.52	137.20
	yes	low	477.81	.
		high	348.47	130.07
		Total	370.03	127.76
	Total	low	307.15	150.91
		high	313.39	144.64
		Total	310.27	140.97
Total	no	low	317.19	146.24
		high	299.79	115.23
		Total	310.87	129.97
	yes	low	461.33	22.42
		high	405.81	139.43
		Total	420.95	119.92
	Total	low	360.44	138.63
		high	370.47	136.81
		Total	365.91	134.41

6.8 Post-test summary and usability of developed technology

This section of the results Chapter discusses the responses expressed by the participants to a series of measures designed to assess their attitudes towards the technology as well as the experiment itself. Initially, the post-test attitudinal results will be summarised, followed by the presentation of the usability characteristics. The sections that have been discussed already within this Chapter; i.e. the participant's perception of their own contribution to the conceptual maps have been omitted here to avoid repetition.

When considering the usability and perceived usefulness of the software and the use and non-use of gestures, participants answered a series of post-test Likert scale measures, based on the scale developed by Smith [2009] ranging from 1 (a positive response) to 7 (a negative response).

The comparisons of the means are reported in Table 6.22 and then described in the remaining sections of this Chapter.

Table: 6.22 Comparison of means of the post-test evaluatory measures.

		N	Mean	Std. Deviation
Rating for the level of ease or difficulty in constructing the CMAP without gestures (scale 1 to 7)	1	10	4.10	1.20
	2	10	5.00	1.41
	Total	20	4.55	1.36
Rating for the level of ease or difficulty in constructing the CMAP with gestures (scale 1 to 7)	1	10	4.10	1.20
	2	10	4.80	1.62
	Total	20	4.45	1.43
Attentive/focused without gestures (scale 1 to 7)	1	10	2.90	1.45
	2	10	3.80	1.40
	Total	20	3.35	1.46
Attentive/focused with gestures (scale 1 to 7)	1	10	2.30	1.25
	2	10	3.20	1.62
	Total	20	2.75	1.48
preference of using controller without gestures	1	10	4.60	1.35
	2	10	3.80	1.69
	Total	20	4.20	1.54
Preference of using controller with gestures	1	10	3.20	1.03
	2	10	2.90	1.66
	Total	20	3.05	1.36
Rating of ease of how to create gestures	1	10	3.50	.97
	2	10	4.20	1.87
	Total	20	3.85	1.50
Rating of ease of how to remember gestures	1	10	2.40	1.35
	2	10	2.70	1.95
	Total	20	2.55	1.64
Rating of appropriateness of gestures	1	10	3.40	1.27
	2	10	4.20	1.48
	Total	20	3.80	1.40
Task difficulty CSYS	1	10	4.30	1.06
	2	10	3.90	1.79
	Total	20	4.10	1.45
Task difficulty IPPDS	1	10	2.90	1.20
	2	10	3.80	1.55
	Total	20	3.35	1.42

6.8.1 Usability and the perceived impact of controllers

Participants were asked to rate the ease or difficulty of constructing the selected concept map using the varying modes of input and gestures across conditions, i.e. between and within groups.

The responses for ease/difficulty of use for one vs. two-controllers without gestures is summarised in Figure 6.9.

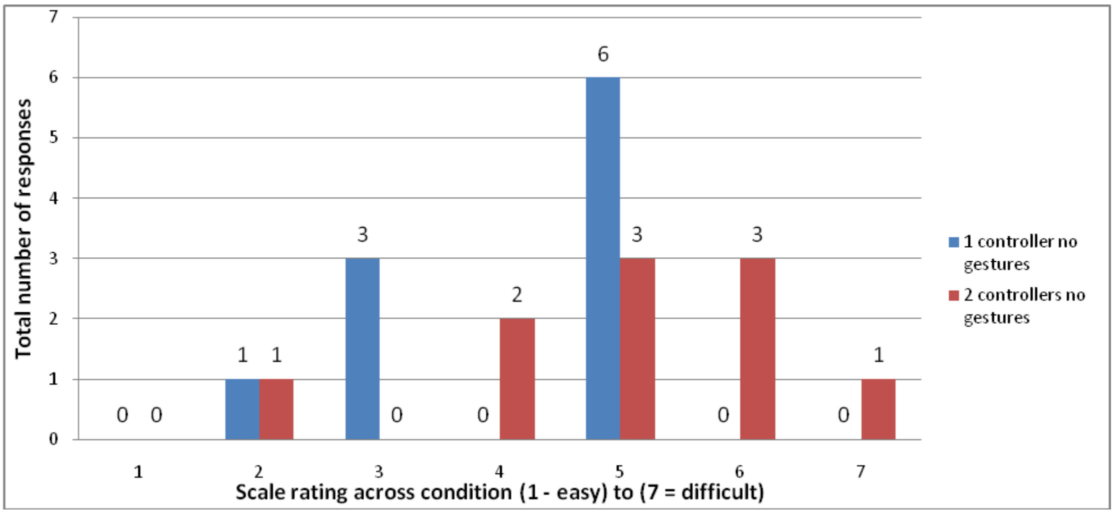


Figure 6.9: Total responses against the rating score when constructing a concept map for one and two-controllers with gestures disabled (between groups factor).

The participants who used one-controller without gestures expressed a mean ease of use score of (M=4.10, SD=1.20) compared to those participants who used two-controllers (M=5.00, SD=1.41). Therefore as a between groups factor, the ease of use was easier for the one-controller condition. This is also true for the use of gestures with variable controller configuration. Figure 6.10 summaries the frequency of reported responses for the ease/difficulty of use for one vs. two-controllers with gestures enabled.

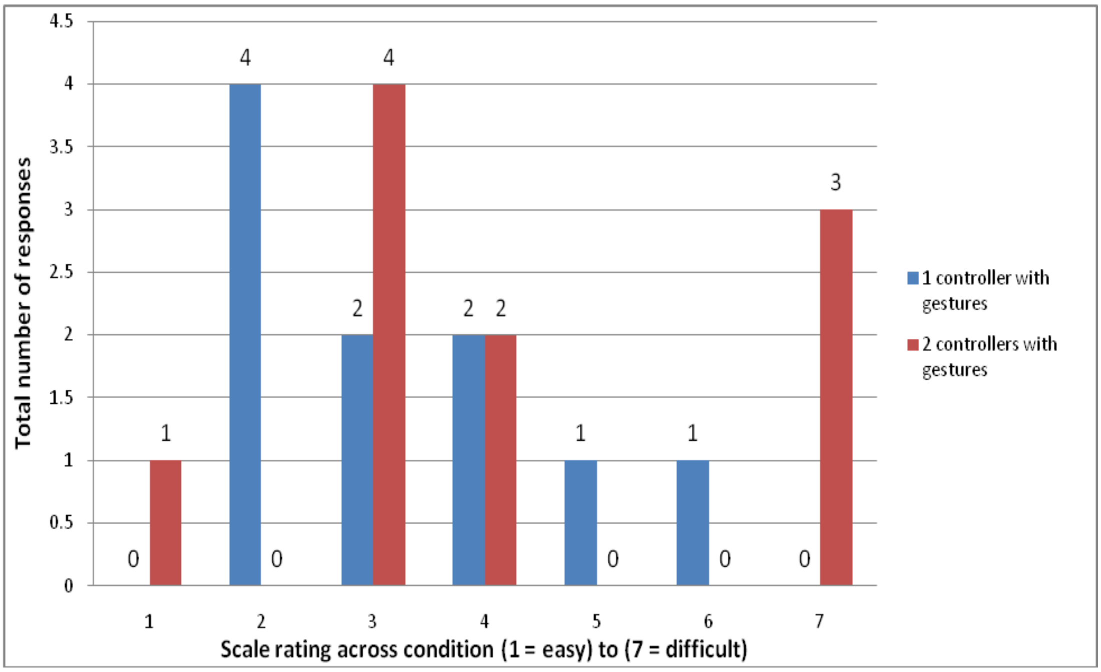


Figure 6.10: Total responses against the rating score when constructing a concept map for one and two-controllers with gestures enabled (between groups factor).

The participants who used one-controller with gestures enabled expressed a mean ease of use score of (M=4.10, SD=1.20) compared to those participants who used two-controllers (M=4.80, SD=1.41). Therefore, as a between groups factor, the ease of use was easier for the one-controller condition.

6.8.2 Usability and the perceived impact of gestures

Participants were asked to rate the ease or difficulty of constructing the selected concept map using the varying modes of input and gestures across conditions, i.e. between and within groups. The frequencies of ease/difficulty of use for the within groups factors of gesture use/non use are summarised in Figure 6.11 for one-controller and Figure 6.12 for two-controllers.

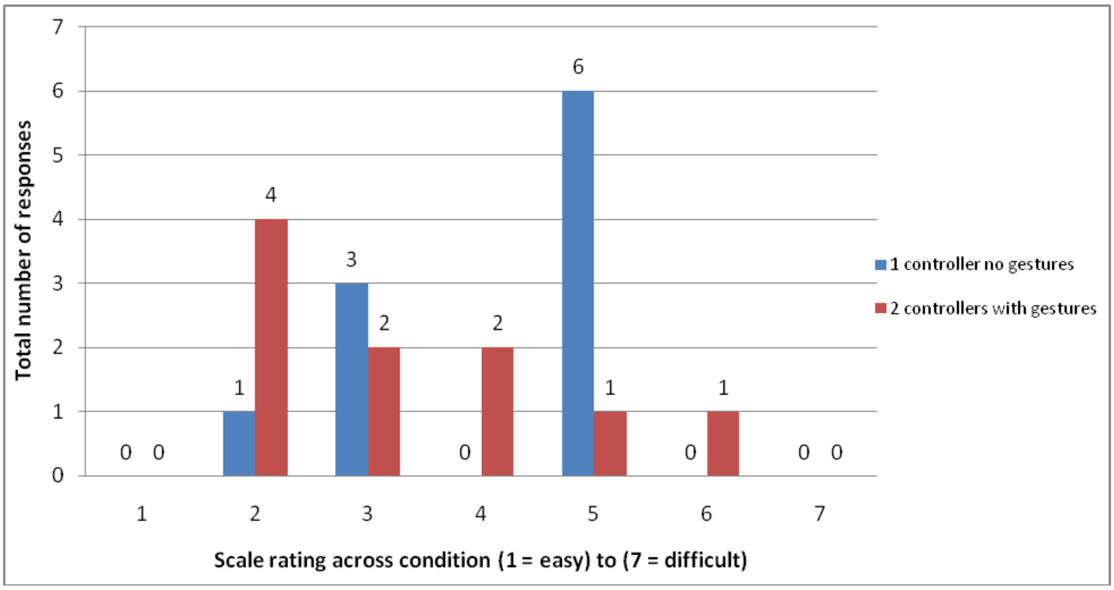


Figure 6.11: Total responses against the rating score when constructing a concept map for one-controller with variance of mode of input (within-groups factor).

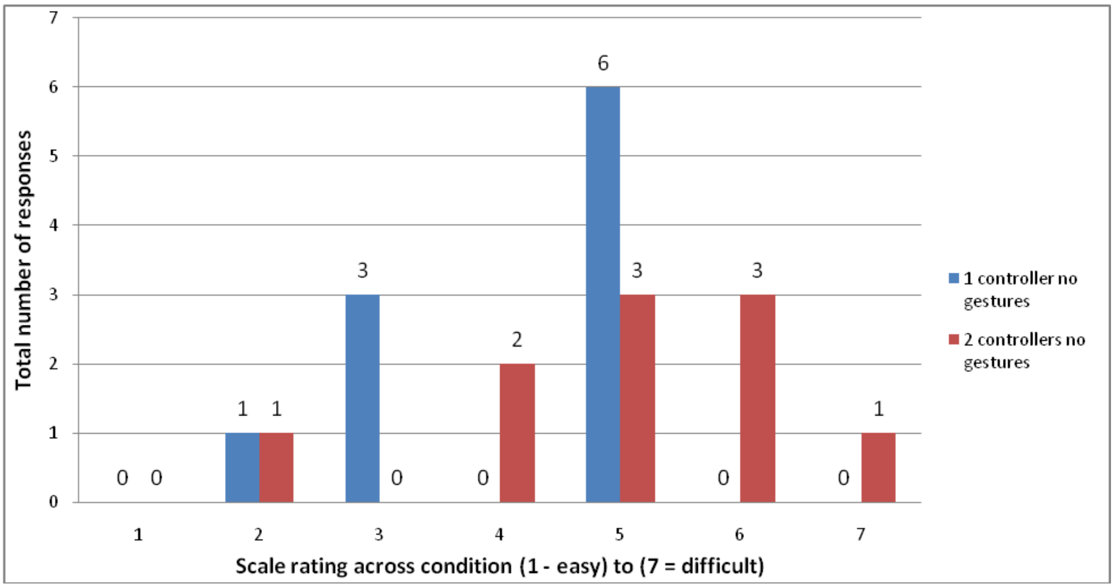


Figure 6.12: Total responses against the rating score when constructing a concept map for two-controllers with variance of mode of input (within-groups factor).

With regards to the ease of use when constructing the concept map without gestures to the use of gestures within groups the mean rating for non use of gestures for one-controller is (M=4.70, SD=1.567) compared to the use of gestures with one-controller (M=4.40, SD=1.174). Therefore, within groups the use of one-controller without gestures was marginally harder to use than the one-controller with gestures enabled.

This was also true in the two-controller condition where the non use of gestures (M=4.80, SD=1.69) was harder to use than with gestures (M=4.10, SD=1.10).

6.8.3 Usability and the perceived preference of gesture vs. non-gesture usage

Participants were asked to rate their preference level when using the controller without gestures, and then with gestures for each of the conceptual mapping tasks using Likert scale measures, ranging from 1 (like) to 7 (dislike). A summary of all participants' responses are summarised in Figure 6.13 without gestures and with gestures.

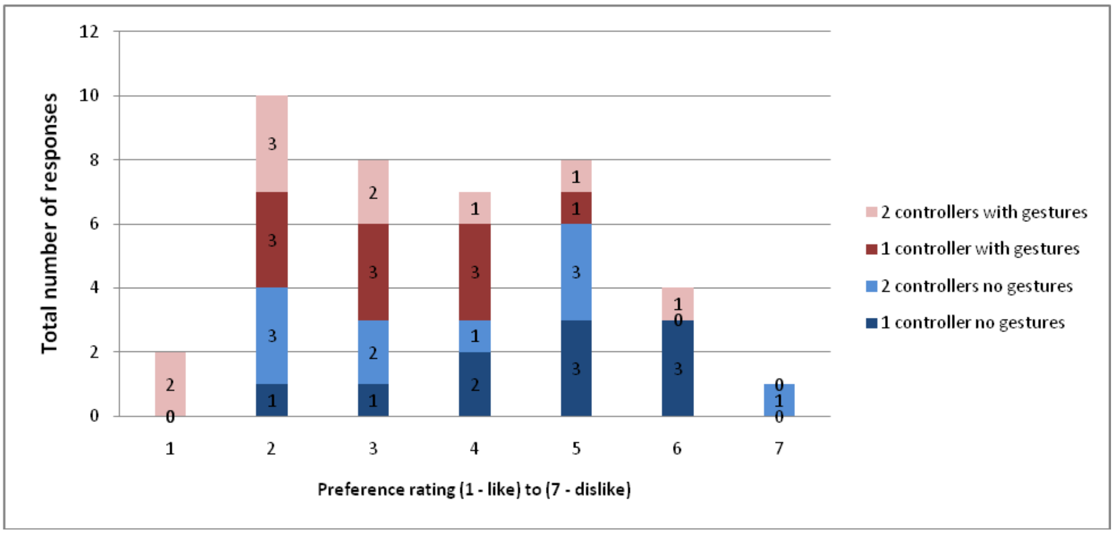


Figure 6.13: Preference levels when using the controller(s) with and without gestures.

The participants preferred to use the controllers with gestures when using the controllers as a two-controller configuration (M=2.9, SD= 1.66) as opposed to (M=3.80, SD=1.69, without gestures). This pattern was also repeated for one-controller usage with a higher preference rating for gestures (M=3.20, SD=1.033) as opposed to non gesture usage (M=4.60, SD= 1.35).

Within groups (i.e. groups 1-6) the mean preference rating for without gestures and one-controller was 4.6 and with gestures and two-controllers

3.2. Within groups (i.e. groups 7-12) the preference rating for without gestures and one- controller was 3.8 and with gestures and two-controllers 2.9. Two controller usage, irrespective of gesture on non gesture usage was therefore preferred according to these preference levels

6.8.4 The ability to create gestures

Participants were also asked to rate how easily or difficult they found it to use gestures for the concept maps using Likert scale measures, ranging from 1 (easy) to 7 (difficult). A summary of the findings are provided in the frequencies of responses by controller condition in Figure 6.14.

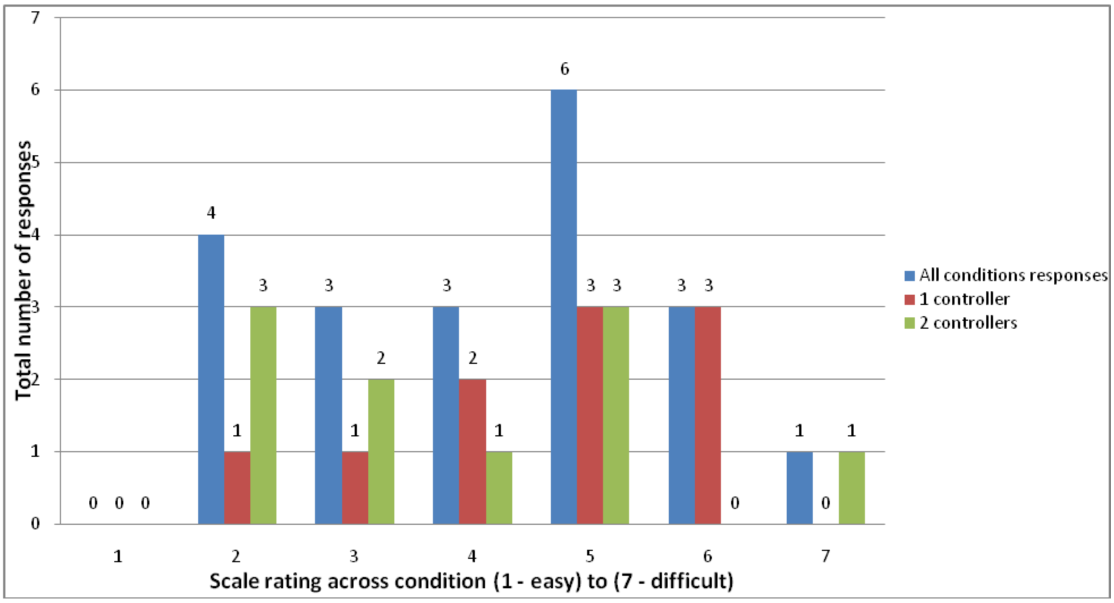


Figure 6.14: Self-reported preference levels for the ease or difficulty of creating gestures, for all participants, as well as the participants who used one-controller, and two-controllers.

As Table 6.24 has shown, those participants who used one-controller found it on average easier to create gestures (M=3.50, SD=0.97), as opposed to those participants who created gestures with the two-controller option (M=4.20, SD=1.87). Such a change is likely to be due to the behaviour demonstrated in the video recordings whereby participants that struggled with the gesturing withdrew from gesturing, whereas in the one-controller condition they adapted their behaviour and assisted in the direction of the gesture user.

6.8.5 Usability summary

Finally, a one-way ANOVA was conducted to evaluate the influence of configuration and use of controllers on the post-test measures (see Table 6.25). The independent variable was the number of controllers and the dependent variables were the post-test measures.

There were no significant main effects on these measures.

6.9 Observational/ interview data and usability

6.9.1 Recognition rate

With regards to the recognition rate it was observed that some participants were able to master the gestures more quickly and efficiently than their partners. In some cases this resulted in partners being disheartened and withdrawn from the process as discussed in section 6.5.1. As a result it is possible that the rate of recognition may have an impact on how users engage with the concept mapping software and work in the group. Rather than empowering the participants, the groups with two controllers and gestures might find themselves disenfranchised by gestures due to learning rates not associated with controller usage without gestures.

6.9.2 Predictive text

Such disenfranchisement might again occur with regards to the predictive text functionality which may lead to a quicker uptake for some participants over others and a subsequent division of labour around these interfaces, as might be the case with gesture recognition rate. Largely the use of predictive text with regards to its use with large-screens was received positively. When asked ‘What did you think of the predictive text?’ some of the responses were as follows:

Two controllers.

S1: Predictive text was useful – a QWERTY keyboard layout would have been problematic, as in both conditions the Wiimote was used as a mouse to select characters. Some of the words we wanted to use (things like CSYs and PDS- acronyms for our modules) weren't in the dictionary, so we had to enter them manually, which became easier to do as we familiarized ourselves with the system.

S2: I am not a fan of predictive text, but i think that if i did use it and it learnt which words i used the most and so would be right a lot more then i would use it.

S5: It was mostly good, although if I remember correctly there were some problems adding suffixes like ing to words. But it generally worked well.

S6: Yeah, what would be quite nice is if you had a small keypad on the remote like a qwerty keyboard, this may be able to input text quicker, I think it would get quite tedious if you had to write a lot with predictive text.

S8: I thought it was a good idea, because the experiment would have been a hell of a lot harder with a virtual keyboard. It worked quite well. The important aspect of it is that it should have a wide array of words.

One Controller.

S9: I think the predictive text worked well in itself, but could be improved based on the context of the large screen maybe a larger, transparent version where the partner can work underneath it while i use it over the top.

S10: I think the concept is sound, but the implementation was somewhat lacking due to the differences between it and using a real phone for predictive text.

6.9.3 Non gesture vs. gesture usage

As well as predictive text usage being well received so was the use of gestures. When asked 'What did you think of the gestures as opposed to the non use of gestures?' participants suggested:

Two controllers.

S1: They make it [gestures] a lot easier to use – rather than having to fight the sensitivity of the Wiimote as a mouse as you try to select one of the top-row buttons, you could use the gestures anywhere on the screen and carry straight on with your design. However, when I did it without gestures I found that apart from a shaky first few minutes, I got used to it. Out of the two, I'd prefer using gestures. They're simply a lot easier and quicker to use. Plus they cut down on the sensitivity problem. You don't need to worry about keeping the Wiimote still when performing a gesture.

S2: Using the controller as a mouse took longer but i think it did allow for the user to decide where the bubble appeared on screen instead of using the gesture and moving it. I think another reason was that they made the process of making the diagram faster because i didn't have to select between the buttons at the top.

S5: I thought the gestures were very useful, when they worked, which was most of the time. Good because they saved a lot of time in making the shapes etc. using the controller as just as mouse was ok but, although less likely to get it wrong, took longer and not as interesting/interactive

S6: I think the gestures were good, however I would have used different gestures, simply as I think I would remember them better. The gestures were not always recognised as the ones I was trying to perform. The remote as a mouse is a good idea although it's a bit inaccurate it was very hard to press the buttons on the screen.

One controller.

S9: I'd say using the gestures helped reduce strain on the wrists a bit because they were so varied and it wasn't point and click all the time. The gestures were an improvement I'd say. They're something you can easily get to grips with, and once you've mastered them it's always going to be easier than clicking a small button.

S10: I thought the idea of gestures was good. I'd have preferred button shortcuts to be honest and, the coordination just wasn't there for me compared to an actual mouse.

6.9.4 Engagement

As with any technology some found the use of the controllers with gestures particularly engaging and some did not. When asked ‘Was there any point where you felt particularly engaged or disengaged within the group and/or towards the content?’ ‘Does anything stand out?’ Some typical responses were as follows:

> Two controllers.
>
> S1: I think both my partner and I felt very disengaged as we struggled with the Wiimote as a mouse - there were a few moments, when we'd managed to select the button we wanted, where we managed to build for a minute or two, but they were soon replaced with more struggles. Using the Wiimote with gestures, on the other hand, was very engaging, as the gestures were but momentary distractions, and we were given the chance to focus completely on the map.
>
> S2: With the controllers (and in both the mouse and gesture experiments) we could do a bit of both and that allowed me to engage more e.g. if i had run out of ideas that didn’t stop me doing something instead of not having a controller and not being able to contribute
>
> S5: Using the gestures I guess stood out. Wouldn't say I was disengaged at any point because I was busy throughout the whole time limit.
>
> S6: To be honest not really, however if we only had one remote I’m sure I would have felt disengaged.
>
> One controller.
>
> S3: I felt more engaged when I could clearly remember details about a module, or knew how it related to others. Probably less if I couldn't remember.
>
> S4: The gesture based scenario was the most interesting because I like the gesture interaction with the computer, using the mouse way did drag a little at the end I thought as it was much slower than the gestures. I think the main thing was that gestures improve the time it takes to input data when making a concept map

S9: I think possibly the most disengaging aspect was in text input, when i really couldn't think what to put next, and had to ask XXXX for ideas. Most engaging was trying gestures for the first time and experimenting what makes them work properly etc.

6.10 Chapter summary

This Chapter has outlined the major research questions of this thesis and the results of the experimentation alongside these goals. It has also provided some of the opinions of the software by the users, and also provided a high level view of some of the researcher’s observations.

A summary of the results will now be presented in Chapter 7 before continuing to evaluate and conclude in view of the results initially presented here.

7 Evaluation and conclusion

This Chapter reflects upon the research presented in this thesis and summarises its achievements based on the criteria for success (see section 1.2) defined in Chapter 1. This Chapter also discusses the general research contribution of this thesis as well as its limitations and future work.

7.1 Introduction

This thesis has explored how multiple freehand input configuration and mode of input affect levels and type of interactions recorded when creating co-located collaborative concept maps in front of a large-screen wall-projected display. It has also considered how these experimental conditions might affect levels of social dominance, as well as group input and discussions, when interacting in this way and is grounded in an initial exploratory study by Birnholtz et al. [2007]. At the same time a method has been provided and discussed in Chapter 5 of this thesis to allow users to interact with conceptual maps in an innovative way that meets the need for new tools to support informal learning activities, in particular processes associated with conceptual development demanded by Milne [2007].

While research indicates that using knowledge construction and visualisation techniques can be particularly powerful learning tools, their use is still infrequent in Higher Education in the UK e.g. Kinchin [2001]. Additionally, motivation to use them is low [Farrand et al. 2002] and they are not always received positively by students or teachers [Santhanam et al. 1998]. This is despite the benefits of collaboratively creating concept maps having been well documented in a number of studies, for both co-located and synchronous and asynchronous groups e.g. Cañas et al. [2003].

While the use of large displays and projected displays is common-place in most educational settings, research has only recently begun to examine the use of these displays for knowledge creation activities rather than solely the presentation of information e.g. Eppler and Burkhard [2004] and to attend to the differences inherent in using these displays for eliciting rather than representing knowledge [Cañas et al. 2005]. Therefore, what is not clear is how to best interact with large screens for activities that involve the constructing of conceptual knowledge. In general, a number of interaction techniques have been investigated for use with large displays, including natural gestures, voice recognition, multi interaction techniques, and methods to improve the reach of the user. These techniques show promise, but differences across task types need to be explored in more detail [Ni et al. 2006]. This is especially important in terms of how they can facilitate the co-construction of knowledge with concept maps through the potential they offer in engaging and encouraging students to interact with them.

Initial research has indicated that there is a significant need to develop new input devices for interaction with large displays, as devices such as a keyboard or mouse are not sufficient [Ni et al, 2006]. Traditional devices have been designed for applications for the presentation of existing knowledge (e.g. word processing or media-editing applications) rather than the creation of new knowledge or learning experiences [Milne, 2007]. As such, gaming interfaces like the Nintendo Wii, have provided new options for creating gesture-based input commands beyond the move-click capability of a mouse [Milne, 2007]. However, the challenge is to incorporate these devices into existing software structures that could benefit from their use, and to better understand how users interact when constructing concept maps and interacting with them in this way.

Therefore, the contribution of this thesis to the general body of research focuses on interactive, large, projected display technologies (that have become familiar in educational contexts) and gaming interfaces, like the Nintendo Wii, that provide options for creating gesture-based input commands beyond the move-click capability of a mouse [Milne, 2007] offering new ways of interacting with conceptual mapping and large screen based environments.

7.2 Summary and discussion of the results

Before any further interpretation of the results can be completed the results of the experiments must be summarised. Table 7.1 provides an initial summary of the results, followed by a more detailed summary of the results aligned to the major research questions of this thesis, which also discuss these reported findings in the context of the related literature.

Table 7.1 Results related to research findings.

Research Question	Result
RQ1. Does number of controllers and with and without use of gestures influence the amount of interaction in a group when constructing concept maps?	YES- Groups using one-controller afforded higher levels of human to human interaction, with gestures also increasing the number of interactions seen.
RQ2. Does number of controllers and with and without use of gestures influence the type of interaction seen in groups?	YES – One-controller usage resulted in increased numbers of interactions for the ‘shows solidarity’, ‘gives orientation’ and ‘gives opinion’ categories. Gesture usage resulted in increased numbers of interactions for the ‘shows solidarity’, ‘tension release’, ‘gives orientation’ and ‘shows tension’ categories.
RQ3. How does the level of social dominance and controller and gesture configuration influence the amount of interaction in a group?	There were no significant differences on the amount of interaction that occurred in groups that had both low, mixed and high scores for the social dominance constructs.
RQ4. How does the level of social dominance influence the type of interaction in a group?	There was a significant difference for the levels of ‘conversational control’, ‘gives orientation’ and ‘shows solidarity’ on the amount of interactions of that type by group, with higher levels of interaction for all group configurations for one-controller than two.
RQ5. Does level of social dominance influence who uses the controller first?	Levels of influence and poise were significantly affected by initial control of the controller. Correlations between the amount of time in possession of the controller with the social dominance construct scores showed no significant correlations. At the same time, when the controller was initially picked up, the participant who initially did so controlled the controller for longer than those participants who did not initially pick up the controller.
RQ6. What is the relationship between amount and type of interaction and process outcomes (e.g. number of nodes created)?	Analysis indicated that the main effects of number of controllers, gesture and the interaction effect between gesture and number of controllers were not statistically significant for the amount of nodes, words and edges constructed. Results indicated that there were no main effects of high or low node construction on the total number of interactions. High node groups engaged in significantly more disagreements than low node groups.

This research study was designed to test the major hypotheses relating to the main research questions, situated in the context and use of CCM, when using multiple forms of input and with and without gesture usage. This resulted in the construction of the WiiConcept software to enable collaborative concept mapping with large-displays. This extends the work of Stasche [2008] by adding multiple forms of input and applying to a concept map, whilst solving technical challenges as outlined in chapter 4 of this thesis. Having constructed this software, it was then possible to consider how the application of this mode and configuration of input might impact on social dominance, building on initial studies in this area, e.g. Birnholtz et al. [2007] using new forms of technology beyond that of mouse and keyboard. It is in this context that the following research questions are now summarised and discussed having been outlined in chapter 1 of this thesis and discussed throughout.

<u>RQ1.</u> Does the number of controllers and with and without use of gestures influence the amount of interaction in a group when constructing concept maps?

When considering the amount of interaction in a group it was hypothesised that groups would exhibit higher amounts of interaction when using one-controller as opposed to two and with gestures rather than without gestures.

This hypothesis was confirmed with a main effect of number of controllers, with a higher number of group interactions when pairs had one-controller than two-controllers. A main effect of gestures was also evident, with more interactions occurring with gestures, than without gestures. These results suggest that within-groups for one-controller the mean total number of interactions for all groups increased from (M=383) to (M=482) with the number of interactions increasing from (M=250) to (M=370) for two-controllers. Therefore, groups in the two-controller condition, even with gestures (M=370) only begin to approach the lower number of interactions (M=383) witnessed by groups who use one-controller without gestures.

These results agree with previous work which has shown that the social affordances of different interactive displays affect collaboration e.g. Rogers et al. [2004], and that levels of social interaction can be significantly higher when comparing the use of a standard controller to the use of a controller which may encourage interaction e.g. Lindley et al. [2008]. The use of input devices that respond to body movement e.g. the use of gestures, as opposed to the non-use of gestures, therefore, would encourage greater levels of interaction, which has now been reported here in the context of CCM. This would suggest that controllers which encourage natural movements should support the experience of interaction when concept mapping. However, initial evaluatory results indicated that the main effect of the number of controllers on the ease/difficulty in constructing the concept maps, the preference of using or not using gestures to construct concept maps and the rating of ease of ability of creating the gestures were not statistically significant. Additionally, all participants responded that the tool was relatively easy to use and engaging, which suggests that this tool could be integrated into collaborative concept mapping activities, allowing for greater collaborative knowledge building and sharing of knowledge, due to the increased levels of interaction for one-controller with gestures.

The higher levels of interaction seen when using one-controller as opposed to two-controllers can be understood further in the context of RQ4, RQ5 and RQ6. At the same time, however, Birnholtz et al. [2007] found that multiple mice conditions allow for more parallel work, with the quality of discussion higher in the single mouse condition. Moreover, participants were more likely to act in their own best interest in multiple mouse conditions. Therefore, as has been suggested, it is likely that in a two-controller setting, participants will have fewer interactions in a two-controller setting as they are likely to focus on their own areas of the concept map, with the single controller used as a focus of discussion e.g. Birnholtz et al. [2007]. Such a view fits into the wider area of CCM literature in that researchers emphasise that students, in the co-construction of knowledge in a collaborative learning situation negotiate meaning. This negotiation or grounding process is focused on the meaning of concepts e.g. [Baker et al. 1998] and to achieve agreement, i.e. on a concept for example, it is often necessary to integrate different points of view which, due to the reduced number of interactions in the two-controller condition, no longer occur. Crucially Roth and Roychoudhury [1993] found that during moments of controversy, students referred to prior problems, previous experiences or to some authority, with concepts more likely to occur when the other participants resorted to longer explanations and justifications of their statement. With reduced levels of interaction it is certainly possible that these negotiations were reduced in number, however, it is therefore important to determine the influence the number of controllers and non/use of gestures have on the types of interaction seen in the groups.

<u>RQ2.</u> Does the number of controllers and with and without use of gestures influence the type of interaction seen in groups?

There was a significant effect of controller usage and the amount of interactions that occurred for the 'shows solidarity', 'gives orientation' and 'gives opinion' categories, with more interactions of these types occurring when using one-controller as opposed to two-controllers. These systems of categories suggest that there is some evidence that when, using a single controller, groups are able to give orientation and their opinion freely, with instances of solidarity occurring if, and when, things go wrong, as focus is shared amongst group members, and activities carried out by one person are likely to be noticed by others. Thus, it may be harder for members involved in negotiation through the use of one-controller to act explicitly in their own best interest. Indeed, from the video observations the process involved participants expressing solidarity when not in possession and when in possession of the controller, yet there were, of course, instances where participants would withdraw from the group process after a controller hand-over. However, it would appear that solidarity was shown within groups, with free expression of opinion and orientation. It would be interesting to see, however, if this orientation is contextualised in a positive or negative context for example if the participants were complete strangers working together on a task for the first time. Furthermore, these participants were 'friendly' to each other and knew each other before meeting and it would be useful to ascertain if these interaction categories were also repeated for groups of strangers.

With fewer interactions of these types expressed in the two-controller condition, there is a suggestion that the multiple controller condition allowed for more parallel and individualistic work in that while there were still interactions of this type they were less frequent. This is also represented by the smaller number of interactions of all types which occurred when using two-controllers as opposed to one-controller. At the same time, the quality of discussion of the one-controller condition was deemed to be higher than in the two-controller condition, which is in line with other findings in this field i.e. Birnholtz et al. [2007]. As such, whilst there was a reduction in the levels of group interaction with regards to the 'gives opinion' and 'orientation' categories this did not transfer to significant levels of tension and antagonism. Interestingly, where this did occur, was with regards to the use and non use of gestures.

The exploration of the hypothesis that higher levels of tension and antagonism may occur when using gestures, as opposed to without, is grounded in the context that recognition accuracy for detecting gesture command should be high, with nearly 100% accuracy required for user satisfaction [Kela et al. 2006] since too many mistakes may cause the user to become frustrated or at worst abandon the method. As a result, it was found that there was also a significant effect of gesture usage for the 'shows solidarity', 'tension release', 'gives orientation' and 'shows tension' interaction categories, with more interactions of this type occurring when using gestures than without. In this context the showing of solidarity, the expression of orientation and the showing of tension are focused on the use of gestures. What may reduce the areas of tension, and, therefore, increase social-emotional positive reactions would be to provide personally orientated gestures, which would increase recognition rate, with initial studies indicating that people prefer to define personal gestures e.g. [Kela et al. 2006].

RQ3. How does the level of social dominance and controller and gesture configuration influence the amount of interaction in a group?

There was no main effect of the social dominance constructs and the total number of interactions encountered. Due to the lack of variation in the scoring of the influence and poise construct no statistical significance was observed for either controllers or without or with gestures. This is also true of the type of interaction and, therefore, there was no statistical significance reported here either. The self assurance construct, where pairs used one-controller (with both low scores) have higher levels of interaction than pairs with both high self assurance scores, however, any conclusions surrounding this construct should be considered with caution due to the low level construct reliability score reported.

These findings, therefore, suggest that the amount of interaction for low and mixed score groups, in the 'conversational control' construct was higher for one-controller usage than two, with both high score groups exhibiting increased interaction when in possession of two-controllers. As control of conversation determines the extent to which any participant in a group negotiation is perceived to monopolise or take charge of the conversation it is possible that single controller possession acts as a stimulator for interaction in the low groups and as a proxy for conversational control in the mixed groups when using one-controller. However, where high levels of conversational control occur; more interactions are exhibited than in the one-controller condition as participants in these groups feel that in not having to worry about device control, they are free to focus upon the process of interacting. Given that human perception is typically focused in a single point of activity, it can be difficult to maintain levels of interaction, particularly when these are displayed across a large-screen display, perhaps indicating that a single input device configuration, (through which focus is shared amongst group members), activities carried out by one person are likely to be noticed by others, which when considering low and mixed conversational control groups result in fewer interactions. However, where groups are conversationally confident, members involved in the construction of concept maps are able to act explicitly in their own best interest and therefore maintain a higher level of interactions, as they battle to control conversation.

Such findings are in contrast to Birnholtz et al. [2007] who found that input configuration did not affect social dominance as measured using Burgoon's [1998] scale.

Additionally, and in the context of group discussion, when considering the average rating score for quality of discussion, a significant main effect of number of controllers occurred for this measure, with a higher mean rating achieved with one-controller than with two-controllers. At the same time, when considering the effectiveness of discussion a significant main effect of number of controllers occurred with a higher mean rating achieved with one-controller than with two-controllers suggesting that conversational quality and effectiveness was improved when using one-controller as opposed to two. When considered in the context of RQ1 the increased amount of interaction is also associated with improved conversation and increased effectiveness. Such group discussion findings were also confirmed by Birnholtz et al. [2007].

<u>RQ4.</u> How does the level of social dominance influence the type of interaction in a group?

It was predicted that levels of social dominance would influence the type of interaction seen within groups, and the associative context of controller configuration. Due to the lack of variance reported in the sample for the influence and poise constructs, as well as the self assurance constructs (which additionally had a low measure of reliability) it was not possible to consider these aspects of social dominance within this context. It is also worth noting that these two constructs were also dropped from further consideration by Birnholtz et al. [2007]. Therefore, the level of social dominance influence upon interaction types focuses on the conversational control social dominance construct.

For the conversational control construct, there was a significant main effect of group conversational control score on the ‘gives orientation’ and ‘shows solidarity’ construct, with a higher number of interactions for low, mixed and high scores of this type when dyads that had one-controller as opposed to two-controllers. Therefore, for all levels of social dominance within groups, groups were inclined to raise other’s status, give help and reward, give information, repeat and clarify information, when using one-controller as opposed to two-controllers suggesting that the use of one-controller affords such behaviour more so than that of two-controllers.

The main effect of group conversational control score for the ‘disagrees’ interaction construct was not significant, with a higher number of interactions of this type when dyads had one-controller for low and mixed score dyads than two-controllers. Higher score dyads had marginally higher levels of this type of interaction with two-controllers. Therefore, where both group members had high levels of conversational control there was more, but not a significant amount of disagreement when participants had two-controllers than with one suggesting that these group members were more likely to show passive rejection, and withhold help when working together than when working with group members that also tried to control the conversation. At the same time, therefore, the interaction effect of group conversational control score and number of controllers for the ‘shows tension release’ category interaction constructs was not significant although there was a marginally higher number of interactions for low, and mixed scores of this type when dyads had one-controller as opposed to two. Higher score dyads had marginally higher levels of interaction with two-controllers than one-controller.

<u>RQ5.</u> Does the level of social dominance influence who uses the controller first?

When the controller is initially picked up, the participant who initially did so controlled the controller for longer than those participants who did not initially pick up the controller. This was statistically significant. As participants had free choice as to who initially picked up the controller, the initial controller of the WiiRemote controller maintained possession throughout the experiment. However, when considering the number of controller exchanges in relation to time, the amount of handovers were more frequent and when using gestures than when not using gestures. Therefore, the use of gestures could be perceived as acting in a levelling way, whereby the use of gestures resulted in more frequent changes of the controller. Observations from the video analysis corroborate this finding though more work is needed to quantify this phenomenon. It would seem that when using one-controller without gestures the dominant user can control the controller for longer, and relinquish control less often. On the other hand, and due to the lack of experience with gesturing of the sample, more transferences of the controller occurred due to the inability to gesture consistently. Where errors in the gesturing occurred, greater democracy in controller possession subsequently occurred. Although, the analysis of interaction types by controller handover would quantify this observable claim.

At the same time, comparisons between the amount of time in possession of the controller with the social dominance construct scores showed no significant correlations. Levels of influence and poise were significantly affected by initial control of the controller. Therefore, the perceived degree of impact a participant has on others in winning them over to his or her point of view, and the extent to which a person is perceived as being able to make decisions and take decisive action, is affected by the amount of time in possession of the controller when concept mapping with and without the use of gestures, with no consistent differences reported by Birnholtz et al. [2007] for example.

<u>RQ6.</u> What is the relationship between amount and type of interaction and the concept map process outcomes?

As reported, in relation to RQ1, there was a main effect of number of controllers and use of gestures on the total amount of interaction, with groups in the one-controller condition showing significantly more interactions than groups in the two-controller condition, and more interaction occurring in both conditions when gestures were used.

Correlations between the total number of interactions and the number of edges, conceptual nodes and total number of words were calculated to determine the relationships between these measures. It was assumed that the number of edges and nodes would be highly correlated and that those who interacted more might create more nodes, edges and words. The results indicated that there was no correlation between number of interactions and number of edges, words and nodes created by groups. As was expected, the number of nodes and edges created by groups are significantly positively correlated; with participants linking edges with nodes (although they did not always label these edge based relationships).

The results indicate that there was no difference between controller condition in the number of nodes, words or edges produced by groups, and no relationship between the amount of interaction and the number of nodes, words and edges.

To explore whether there was a relationship between the number of nodes created and the total number of interactions groups were identified as either high node or low node groups using a median split. A score of >12 nodes were determined to be a high score and a score of 12 nodes or less was classified as being low (the reasoning behind this split is outlined in section 6.6).

Results indicated that there were no main effects of high or low node construction on the total number of interactions, indicating no relationship between whether groups created a large or small number of nodes and the amount of interactions. However, when exploring differences between high and low node creation and particular types of interaction behaviours, results indicated that the difference between high and low node groups was not significant for disagreements, however high node groups engaged in significantly more disagreements than low node groups.

It would appear, therefore, that the number of nodes created is not influenced by the use of one or two-controllers or the use or non use of gestures. Although there is some evidence to suggest that engaging in disagreement was related to the amount of nodes created with disagreement leading to more nodes. This is in contrast to network supported collaborative learning whereby it has been found that group concept mapping performance was significantly correlated to the quantity of group interaction, particularly high-level interaction processes e.g. Chiu et al. [1999]. This is despite all participants responding that the tool was relatively easy to use. Further research, over a longer period of time, may see improvement with this form of interaction, with increased mastery of gestural movement leading to greater detail of conceptual mapping.

As a result, whilst seeing increased amounts of interaction when groups were gesturing as opposed to non gesturing the increased levels of interaction did not influence the final concept map in terms of the number of nodes, words and edges created. To determine whether there was any impact upon the quality of the information contained within the nodes, assessment against expert level concept maps in terms of interaction and domain may be further investigated.

7.2.1 Contribution

This thesis extends initial research into students' face to face interactions with collaborative concept maps, in the context of social dominance and applied it to the emerging areas of more natural interfaces and their subsequent use with large-screen displays. Such an investigation has led to a more complete understanding of how configuration and mode of input effect group interactions when collaboratively concept mapping in this context. The software that allows this investigation has also been presented, via the integration of WiiRemotes with large displays for a concept mapping task, creating a unique tool through which concept maps can be collaboratively created on large displays.

The benefits of collaboratively creating concept maps have been well documented in a number of studies, for both co-located and synchronous and asynchronous distant groups e.g. Basque and Lavoie et al. [2006]. These studies show that collaboratively developing concept maps is particularly helpful for understanding complex and ill-structured information [Jonassen et al. 1993]. Researchers point towards the fact that collaboratively building a concept map requires students to discuss the content, repeatedly assessing and revising their structures, until they have created a joint understanding through the process of creating a concept map [Jonassen et al. 1993], which may be the mechanism through which they improve learning.

Further evidence of these mechanisms comes from studies that contrast face to face and asynchronous groups, which indicate better outcomes for face to face, rather than asynchronous and moderated distant groups e.g. Basque and Pudelko [2004], reiterating the importance of jointly constructing concept maps to attain maximum learning benefits. As with other studies of collaborative learning e.g. Mercier, Goldman & Booker, [2009] most research on collaborative construction of concept maps find that the quality of the interactions between participants has a huge impact on the outcomes for the group [Cañas et al. 2003]. Results from these studies found that more complex interactions and elaborate discussions led to better concept maps.
While the use of large displays is common-place in most educational settings, research has only recently begun to examine the use of these displays for knowledge creation activities rather than solely the presentation of information e.g. Eppler, and Burkhard [2004] and attend to the differences inherent in using these displays for eliciting rather than representing knowledge [Cañas et al. 2005]. Therefore, what is not clear is how to best interact with large screens for activities that involve the constructing of maps of conceptual knowledge. In general a number of interaction techniques have been investigated for use with large displays including natural gestures, voice recognition, multi- interaction techniques, and methods to improve the reach of the user. These techniques show promise, but differences across task types need to be explored in more detail [Ni et al. 2006]. This is especially important in terms of how they can facilitate the co-construction of knowledge

with concept maps through the potential they offer in engaging and encouraging students to interact with them, which is the aim of the research presented here.

Research has indicated a significant need to develop new input devices for interaction with large displays, as devices such as a keyboard or mouse are not sufficient [Ni et al. 2006]. Traditional devices have been designed for applications for the presentation of existing knowledge (e.g. word processing or media-editing applications) rather than the creation of new knowledge or learning experiences [Milne, 2007]. Such a rapidly changing environment requires new technologies that allow students to develop skills in interacting and sharing ideas.

7.3 Criteria for success

At the beginning of this thesis, a set of criteria were given through which this research could be judged in terms of its success. This section in this Chapter examines each criterion and discusses the extent to which it has been achieved. Following this discussion, threats to the validity of the data will be discussed, (see section 7.6 of this Chapter) as well as considering the limitations of this research (see section 7.7 of this Chapter) and the future directions that could be undertaken (see section 7.8 of this Chapter).

7.3.1 *To better understand the role gesture vs. non-gesture and multiple use of controllers with regards to the amount and type of group interaction.*

Chapters 5 and 6 outline the method and subsequent results of this investigation, and have noted how groups using large displays with one-controller afforded higher levels of human to human interaction, with gestures also increasing the number of interactions seen. One-controller usage also resulted in increased numbers of interactions for the ‘shows solidarity’, ‘gives orientation’ and ‘gives opinion’ categories. At the same time gesture usage resulted in increased numbers of interactions for the ‘shows solidarity’, ‘tension release’, ‘gives orientation’ and ‘shows tension’ categories. This was assessed through the novel application of Bales’ [1950] IPA in this context.

7.3.2 *To determine what relation levels of interaction have on the construction of conceptual knowledge i.e. are different numbers of nodes constructed in concept maps when varying the mode and configuration of input?*

If varying the mode and configuration affects the amount of interaction and type of interaction, it is possible that the amount of productive work on the final product would be affected i.e. due to the possibility that they were using a new form of interaction (i.e. gestures) and would, therefore, struggle to complete as many nodes, when compared to a non-gesture condition. It was shown in Chapter 6 that this was not the case, with no effect of these modes of input on the final concept maps produced. Where limitations might occur relate to the amount of time available to construct the concept map, for example.

7.3.3 *To encourage and motivate students to consider their conceptual understanding of computer science modules, through innovative interaction techniques which emphasise immersive and visual properties and to investigate the way such techniques inform the construction of conceptual understanding beyond traditional desktop based displays.*

To exploit the opportunities afforded by interactive displays and the possibility of engagement and increased interaction through the use of gestures, it is also important to understand how such factors i.e. the physical affordances of a technology affect the kinds of social interactions that will result e.g. Gaver [1996] and Svensson et al. [2001]. Compared with a co-located group trying to collaborate around a single PC, keyboard and mouse, large displays offer greater scope for supporting interaction, with this system used in the context of concept mapping to better understand participants’ experiences and interactions with software and environment that affords new ways of interacting with large screens, with the findings of such endeavours reported in Chapter 6.

7.3.4 *Understand whether having initial control of the controller influences social dominance in this context.*

Chapter 5 outlined the method through which social dominance measures were applied to the new context of concept mapping, with multiple users in large displays. An assumption about situating large displays in these kinds of settings is that they provide a large interactional space that can support more 'fluid' kinds of collaborative interactions e.g. Rogers and Lindley [2004] and Johanson et al. [2002], however, initial investigations into social dominance with these displays in the context of negotiation have limited freedom of movement due to the use of cabled mice and fixed seating positions e.g. Birnholtz et al. [2007]. As such, evidence suggested in Chapter 6 that initial use of the controller did influence aspects of social dominance when concept mapping.

7.3.5 *To develop a proof of concept prototype tool to demonstrate the multiple use of multiple WiiRemote controllers with and without gestures.*

Chapters 2 and 3 identify the educational and technological requirements for investigating how groups interact with a large display using multiple controllers with and without the use of gestures, and considers socio factors of the use of different kinds of interaction style (e.g. multi-user gesturing and multiple input devices and how varying these factors impacts upon the amount and type of interaction when working in the context of large displays). Having identified this need, Chapter 4 outlined the method through which this environment was achieved.

7.4 Limitations

7.4.1 Limitations of environment

As the experiments were completed in a research classroom, (because the participants were not required to concept map as part of their normal curriculum and, therefore, could not be observed under normal circumstances?) a common concern with experiments of this type is that it was carried out within a ‘laboratory setting’. As such, generalisations beyond this setting must, therefore, be considered with caution.

7.4.2 Task limitations

While the laboratory aspects of the study are one issue, the relevancy of the material that the students were constructing is another consideration. Whilst the content, that of computer science modules, was familiar to the participants, they were asked to complete a task they were largely unfamiliar with i.e. reflecting on their course content. This, when combined with being asked to learn a new system and reflective process might have increased cognitive load and reduced the number of interactions, and possibly affected the types of interactions.

A further limitation of the study might also therefore be with regards to the training of the participants and the resultant factor of overall time spent concept mapping.

To reduce the impact of cognitive load, participants could have been given the conceptual map training at a different time than before the session. As such, the participants were provided with an introduction to concept mapping before the session (although they were given example literature when agreeing to complete the session), as well as an introduction and exploration of the software before testing. Being introduced to concept mapping and the software in the same session may, therefore, have influenced the amount of interaction, and type of interaction. However, this is also true of the alternatives in that a session could have been run prior to the experiments, at which point participants could have forgotten the conceptual mapping process and spent their time reflecting on this rather than engaging with the task. To a certain extent, therefore, it is possible that a large amount of the interactions are task orientated in the initial condition.

At the same time as running these introductory sessions to the concept maps and software, and as well as completing the questionnaires between experiments the participants had effectively been involved for two hours. As a result students might have become fatigued in the final session, which may have impacted upon their levels of energy, enthusiasm and subsequent interaction. However, to get any meaningful amount of information with regards to a concept map in a session shorter than this time would have been impossible. In fact, when considering the content of these concept maps, a longer study, with concept maps created and added over time would be preferable.

7.4.3 Sampling limitations

Limitations were apparent with regards to the sampling of the participants, and the subsequent ability in being able to make wider generalisations about interacting with concept maps via the modes undertaken here.

Because all groups were male, there was no way of investigating the effect of the controller usage (configuration and mode) upon the levels of social dominance for mixed groups as well as all female groups. As such, further work might consider the influence of gender when interacting with concept maps in this way. At the same time, these gender based limitations extend to ethnicity, as well as age and further research would need to be made with varying group participants to ensure the reliability of these results when looking to make wider generalisations.

Furthermore, the participants were limited to computer science students. Therefore, generalisations beyond the area of computer science should also be avoided. Rather, further research might also see students from other courses and in other faculties interact in this way and consider comparisons between their levels and types of interaction. Furthermore, it would also be useful to do so at a number of university sites and league table positions.

As the students were all computer science students at the same university they knew each other, (although to varying degrees). Total strangers may interact differently when using the input configuration and mode of the device when interacting with each other, and especially in terms of social dominance. Total strangers for example may behave more naturally as they do not necessarily have to see that person again, whereas those from the same social network might see a colleague and think that they are more academic than them based on factors such as exam results in this setting and therefore be less dominant when interacting.

On the other hand, if the participants had been total strangers, then setting up and carrying out a task where total strangers were asked to work together on a novel task, might have placed participants under an unusual amount of stress and pressure, resulting in extremes of interactions than would be seen normally. As such, it was therefore important to ascertain the level of predisposition of familiarity, although further work might wish to consider comparisons between groups of strangers and non-strangers.

Finally, as participants were volunteers, (with the incentive of a randomly distributed prize of money) their motivation to engage fully in the task and to give complete answers in the pre- and post-test is perhaps also questionable.

7.4.4 Software limitations

As the gestures were pre-defined by the researcher, with a gesture set and recording rate, (as outlined by Schlomer et al. [2008]), the observed recognition rate of the gestures was not optimal. This was because the gesture set was not individually tailored to each participant, but instead recorded by the researcher, to reduce the cognitive load placed on the participant having to train the system and also the experimentation time by having to do this individual training. As a result, the gestures were sometimes confused by the participants which may have influenced preference levels with regards to this form of input. Future work should, therefore, focus on ensuring near 100% recognition accuracy for detecting gesture commands with this mode of input when interacting with these devices and the PC. As Kela et al. [2006] agree ‘nearly 100% accuracy is required for user satisfaction since too many mistakes may cause the users to abandon the method’. As a result, and if the task had related to summative work, it is possible that the participants’ attitudes to the software may have differed as the end product here did not matter as much. As such, this may have resulted in changes in level and type of interaction exhibited. To remedy this, it is possible that individuals could have personalised their gestures, however, this involves the laborious technique of training the system, which then may have affected their perception and subsequent usage of the modality as well as their levels and type of interaction. Future work, may therefore like to consider ways through which to incorporate these personalised gestures to increase recognition rate.

Another limitation of the software was the mode used to input the text, that of the predictive text. It was apparent from the video observations that participants struggled to make the cognitive association between the screen and the controller, in that they seem to lose all kind of association between the two. Interestingly, techniques for resolving problems associated with predictive text used on mobile phones did not translate to their use in large-screen environments and this method of input requires future consideration and refinement.

The participants became frustrated when a word was not recognised in the dictionary. Additionally, performance issues caused by lag affected the sensitivity of the controllers which, although infrequent, were frustrating.

7.5 Conclusions

Results indicated that one-controller afforded higher levels of interaction, with gestures also increasing the number of interactions seen. One-controller usage also resulted in increased numbers of interactions for the ‘shows solidarity’, ‘gives orientation’ and ‘gives opinion’ categories, whilst gesture usage resulted in increased numbers of interactions for the ‘shows solidarity’, ‘tension release’, ‘gives orientation’ and ‘shows tension’ categories.

This increase in amount of interaction also saw a significant main effect of the number of controllers occur for the self perceived quality of discussion between partners, for one-controller as opposed to two-controllers. At the same time, when considering the effectiveness of discussion a significant main effect of the number of controllers occurred for with one-controller as opposed to two-controllers suggesting that conversational quality and effectiveness was improved when using one-controller as opposed to two.

There were no significant differences in the amount of interaction that occurred in groups that had both low, mixed and high scores for the social dominance constructs. There was a significant difference for the levels of ‘conversational control’, for the ‘gives orientation’ and ‘shows solidarity’ categories on the amount of interactions of that type by group, with higher levels of interaction for all group configurations for one-controller than two.

Levels of influence and poise were significantly affected by initial control of the controller. Correlations between the amount of time in possession of the controller with the social dominance construct scores showed no significant correlations. At the same time, when the controller is initially picked up, the participant who initially did so controlled the controller for longer than those participants who did not initially pick up the controller.

Additionally, the results indicate that there was no difference between controller condition in the number of nodes, words or edges produced by groups, and no relationship between the amount of interaction and the number of nodes, words and edges. These findings suggest that collaboratively creating a concept-map is productive with either one or two-controllers, and with and without gestures. However, engaging in disagreement was related to the amount of nodes created with disagreement leading to more nodes. If a particular category of interaction is associated with more nodes, there might be some argument for only using one-controller to promote cognitive conflict within groups.

All participants responded that the tool was relatively easy to use and engaging which suggests that this tool could be integrated into collaborative concept mapping activities, allowing for greater collaborative knowledge building and sharing of knowledge, due to the increased levels of interaction for one-controller. As research has shown concept mapping can be useful for promoting the understanding of complex ideas, adopting the WiiConcept tool as part of a small group learning activity may lead to deeper levels of understanding. Additionally, the use of gestures suggests that this mode of input does not affect the amount of words, nodes, and edges created in a concept map.

7.6 Further work

New directions that this work could take are numerous, and fall broadly into the further analysis of the current data, changes based on methodological limitations of the current study (which have been initially highlighted in section 7.6 of this Chapter) and further extensions to the study that examine particular results in more detail.

Further analysis of the current data could include additional case-study work, of high and low performing groups, which could explore further the qualitative data obtained from the hours of video data collected. Particular characteristics of conversation could be analysed to further understand, for example in the one-controller condition, what type of interactions lead to a controller handover?. Was there negotiation or did one person dominate the other by making them take the controller from them when something went wrong?

Further experimentation, as initially discussed in section 7.5, might consider the relationship between prior friendship and its effect upon social dominance and interaction beyond an initial assessment of its possible impact on group interaction and type of interaction and social dominance reported here. Studies, for example, that influence prior friendship on learning have indicated that this can result in better and more complex forms of conversation e.g. Miell and MacDonald, [2000] and it is therefore possible that friendship levels may impact upon interaction types. For example, would somebody be more likely to react calmly or more irritably if the person they were working with was a friend?

Future work should also centre on providing gesture recognition support that is nearer to 100% accuracy. Whilst the gesture recognition provided by Wiigee was adequate, it was by no means perfect and resulted in erroneous gesture recognition, for a relatively low numbered gesture set. Therefore work should be continued in providing more accurate gesture recognition libraries. Consideration of personalised gestures should also therefore be considered. With gesture command found to be natural, especially for commands with spatial association e.g. Kela et al. [2006] and that 'people usually use different gestures for performing the same task' comparison could be made to the levels of interaction for non personalised vs. personalised gesture sets.

Further work might also investigate other input modalities beyond that of gesture-orientated devices e.g. multi-touch devices and how this form of input impacts informs upon interaction levels and types of interaction when collaboratively creating co-located concept maps. Would this be more intuitative than using a gesture-orientated controller? Participants may find it more convenient to sit at a multi-touch desk connected to a large-screen projection and collaborate between, and within, these two contexts. Certainly, until gesture recognition rates are perfected and personalised gestures incorporated unobtrusively within the software design, frustration will remain and such measures might provide a solution to this frustration experienced due to incorrect gesture recognition. Indeed, whilst initially gestures would prove to be engaging, failures due to the recognition process go some way to reducing initial levels of engagement.

At the same time, to avoid pointing issues associated with the sensitivity of the WiiRemote when used as a pointing device, future work should consider the incorporation of the Wii MotionPlus which is an expansion device that allows the WiiRemote to more accurately capture complex motion. Furthermore, with the release of the Wii Vitality Sensor (a fingertip pulse oximeter sensor that connects through the WiiRemote) the device "will initially sense the user's pulse and a number of other signals being transmitted by their bodies, which offer new ways through which to consider interactions when concept mapping.

When considering textual input, careful consideration should be applied to the mode through which text is added. Finding a mode that does not infuriate the user is important, with predictive text input seemingly an ineffective method when precise pointing is required. Often the sensitivity of the controller meant the wrong letter could be selected without the user noticing, and subsequently led to the incorrect spellings of a word. Also, the ability to notice this error at a distance proved difficult for the users, yet more investigation is required with regards to using predictive text as a means through which to interact with large displays. As well as refining the predictive text functionality, further functionality could be included to improve the usability of the system e.g. an undo button and a multiple cut and paste functionality. As the software was initially a prototype there is further scope to improve its functionality and consider the incorporation and development of a gesture set for use with conceptual mapping software, in line with Stasche's [2008] preliminary attempt at doing so for mind mapping.

When groups use a display together, it is not clear how many sources of simultaneous input should be allowed. While single input allows one person to interact physically with the system, multiple inputs, while adding complexity at the system level, allow for more parallel work e.g. Birnholtz et al. [2007]. Further work, might wish to consider if the results presented here are replicated when possibly three, or four controllers are used at the same time, to test the extensibility of the gesture-orientated model presented here.

At the same time, having established the viability of these methods in terms of large displays, this work could be extended to improving the amount and type of interaction displayed in fully immersive CAVE like environments with 3D graphics, due to increased interest in 3D environments brought about by new developments in popular culture, and initial experiments completed by Ball et al. [2007].

Furthermore, whilst the method presented in Chapter 4 presents a creative solution to the problem of integrating multiple WiiRemote cursors into Java based software, such an approach lacks integration with Windows as a whole and therefore the user is limited to the user of multiple WiiRemotes to within the area of the application domain. A more complex solution to this problem would be the creation of a Windows WiiRemote driver or toolkit through which WiiRemotes could be easily integrated for use within a PC environment. However, due to the exploratory nature of developments within the WiiRemote for PC community much needs to be done before this work can be completed.

8 References

[Ackerman, 1996] Ackerman, P, L. 'Adult intelligence'. *Practical Assessment, Research and Evaluation*, 58. Available online at: http://pareonline.net/getvn.asp?v=5and n=8. Last accessed 9th February 2007.

[Adamczyck, and Willson, 1996] Adamczyck, P. and Willson, M. 'Using Concept maps with trainee Physics teachers', *Physics Education,* 31, 6, pp. 374-381, 1996.

[Ahlborn et al, 2005] Ahlborn, B.A. Thompson, D. Kreylos, O. Hamann, B. And Staadt, O.G. 'A practical system for laser pointer interaction on large displays,' in *Proceedings of VRST '05, ACM,* New York, NY, pp. 106-109, 2005.

[Alanis, 2004] Alanis, K. 'Evaluating Technology and Instruction: Literature review Update,' DIIA, The University of Texas at Austin, 2004.

[Alpert, and Gruenenberg, 2000] Alpert, S.R. and Gruenenberg, K. 2000, 'Concept mapping with multimedia on the web,' *Journal of Educational Multimedia and Hypermedia,* 9, 4, pp. 313-330, 2000.

[Argyle, 1988]Argyle, M. *'Bodily communication,'* 2nd ed. London: Methuen, 1988.

[Attygalle et al, 2008] Attygalle, S. Duff, M. Rikakis, T. and He, J. 'Low-cost, at-home assessment system with Wii Remote based motion capture,' in *Proc. Of Virtual Rehabilitation 2008*, Vancouver, Canada, 2008, pp. 168–174, 2008.

[Ausubel, 1968] Ausubel, D, P. 'Educational Psychology: A Cognitive View,' New York: Holt, Rinehart and Winston, 1968.

[Ausubel, Novak and Hanesian, 1978] Ausubel, D.P. Novak, J.D. and Hanesian, H. 'Educational Psychology -A Cognitive View,' New York: Holt, Rinehart and Winston, 1978.

[Baker and Lund, 1998] Baker, M. and Lund, K. 'Promoting reflective interactions in a computer-supported collaborative learning environment,' *Journal of Computer Assisted Learning,* 13, 3, pp. 175-193.

[Bales, 1950] Bales, R.F. 1950. Interaction Process Analysis: A Method for the Study of Small Groups. Addison-Wesley.

[Ball et al, 2007] Ball, R. North, C. and Bowman, D. 'Move to Improve: Promoting Physical Navigation to Increase User Performance with Large Displays,' *Proceedings of CHI 2007,* April 28 – May 3, 2007 San Jose, CA, USA.

[Bamford, 2003] Bamford, A. 'The Visual Literacy White Paper,' Adobe Systems, 2003.

[Baraldi et al, 2008] Baraldi, S. Del Bimbo, A. and Valli, A. 'Interactive Concept mapping through Gesture Recognition on a Tabletop,' in *Proceedings of Concept mapping Conference* 2006, San Jose, Costa Rica, 5-8 September 2006.

[Barenholz and Tamir, 1992] Barenholz, H. and Tamir, P. 'A comprehensive use of concept mapping in design instruction and assessment,' Research in Science and Technological Education 10, 1, pp. 37-52, 1992.

[Barkley, Cross, and Major, 2004] Barkley, E. Cross, K, P. and Major, C, H. 'Collaborative Learning Techniques: A Practical Guide to Promoting Learning in Groups', San Francisco, Cal.: Jossey Bass, 2004.

[Bargh and Schul, 1980] Bargh, J, A. and Schul, Y. 'On the cognitive benefits of teaching,' *Journal of Educational Psychology,* 72, pp. 593-604, 1980.

[Barley 1990] Barley, S, R. 'The alignment of technology and the structure through roles and networks,' *Administrative Science Quarterly,* 35, 1, pp. 61-103, 1990.

[Barr and Tagg, 1995] Barr, R, B. and Tagg, J. 'From Teaching to Learning- A New Paradigm for Undergraduate Education,' *Change,* 27, 6, 1995.

[Basque and Lavoie, 2006] Basque J. and Lavoie, M-C. 'Concept maps: Theory, Methodology, technology' *Proceedings of the Second International Conference on Concept mapping,* Cañas, A, J. and Novak, J, D. Eds. 2006.

[Basque and Pudelko, 2004] Basque, J. and Pudelko, B. 'The effect of collaborative knowledge modelling at a distance on performance and on learning,' in Cañas, A, J. Novak, J. D. and Gonzalez, F, M. Eds. *Proceedings of the First International Conference on Concept mapping CMC 2004,* Pamplona, September 14-17, 1, pp. 67-74, 2004.

[Baudisch, 2003] Baudisch, P. 'Drag-and-Pop and Drag-and-Pick: Techniques for Accessing Remote Screen Content on Touch- and Pen-Operated Systems,' *Proc. Interact 2003*, IOS Press, pp. 57-64, 2003.

[Bellucci et al, 2010] Bellucci, A. Malizia, A. Diaz, P. Aedo, I. 'Don't Touch Me: multi-user annotations on a map in large display environments,' AVI '10, May 25-29, 2010, Rome, Italy, pp. 391-392, 2010.

[Bier and Freeman, 1991] Bier E.A, and Freeman S. "MMM: A User Interface Architecture for Shared Editors on a Single Screen", Proceedings of the fourth annual ACM Symposium on User Interface Software and Technology, November 11-13, 1991, pp. 79-86.

[Billig, 1989] Billig, M. 'Arguing and thinking: a rhetorical approach to social psychology,' Cambridge University Press.

[Birnholtz, Grossman, Mak, and Balakrishnan, 2007]. An Exploratory Study of Input Configuration and Group Process in a Negotiation Task Using a Large Display. Proceedings Large Displays CHI 2007. Proc. Computer Graphics International 2007, pp. 91-100.

[Bleakley and Carrigan, 1994] Bleakley, A. and Carrigan, J, L. 'Resource-based learning activities: Information literacy for high school students,' American Library Association: Chicago, 1994.

[Bligh, 1971] Bligh, D. 'What's the Use of Lecturing?' Teaching Services Centre University of Exeter, 1971 in Davis, B, G. 'Tools for Teaching', Jossey-Bass, 1993.

[Blumenfeld et al. 1996] Blumenfeld, P, C. Marx, R, W. Soloway, E. and Krajcik, J. 'Learning With Peers: From Small Group Cooperation to Collaborative Communities,' *Educational Researcher,* 25, 8, pp. 37-40, 1996.

[Bolter and Gromala, 2005] Bolter, J. and Gromala, D. 'Windows and Mirrors: Interaction Design, Digital Art and the Myth of Transparency,' MIT Press, Cambridge, MA, 2005.

[Bowman, 2005] Bowman, D. A. Chen, J. Wingrave, C. A. Lucas, J. Ray, A. Polys, N.F. Li Q., Haciahmetoglu, Y. Kim, J.S. Kim, S. Boehringer, S. and Ni T., 'New directions in 3D user interfaces,' *The International Journal of Virtual Reality,* vol. 5, no. 2, pp. 3–14, 2005.

[Boyle et al. 2003] Boyle, E, A. Duffy, T. and Dunleavy, K. 'Learning Styles and academic outcome: The validity and utility of Vermunt's Inventory of Learning Styles in a British Higher Education setting,' *British Journal of Educational Psychology,* 73: pp. 267-290, 2003.

[Bransford et al, 1999] Bransford, J. D. and Schwartz, D. 'Rethinking transfer: A simple proposal with multiple implications,' in A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education*, Washington, DC: American Educational Research Association, Vol. 24, pp.61–100, 1999.

[Brufee, 1993] Brufee, K. 'Collaborative learning: Higher Education, Interdependence, and the Authority of Knowledge', 1993.

[Burgoon et al, 1998] Burgoon, J, K. Johnson, M, L. and Koch, P, T. 'The nature and measurement of interpersonal dominance,' Communication Monographs, 65, pp. 308-335, 1998.

[Burkhard and Meier, 2004] Burkhard, R. and Meier, M. 2004, 'Tube Map: Evaluation of a Visual Metaphor for Interfunctional Communication of Complex Projects,' Proceedings of I-KNOW '04, Graz, Austria, June 30 –July 2, pp. 449-456, 2004.

[Buzan and Buzan, 2006] Burzan, T. and Burzan, B. 'The Mind Map Book,' BBC Active, 2006, 1-4066-1020-8.

[Butler, 2001] Butler, A. 'Preservice music teachers' conceptions of teaching ineffectiveness, microteaching experiences, and teaching performance,' *Journal of Research in Music Education,* 493, pp. 258-272, 2001.

[Buxton, 1986] Buxton, W. 'There's More to Interaction Than Meets the Eye: Some Issues in Manual Input' in D.A. Borman and S.W. Draper Eds. *User Centred System Design: New Perspectives on Human Computer Interaction*. Lawrence Erlbaum, Hillsdale, N.J. USA, pp. 319-337, 1986.

[Buxton et al, 2000] Buxton, W. Fitzmaurice, G. and Balakrishnan, R. 'Large Displays in automotive design,' *IEEE,* 2000.

[Cao and Balakrishnan, 2003] Cao, X. and Balakrishnan, R. 'VisionWand: interaction techniques for large displays using a passive wand tracked in 3D,' *Proceedings of the 16th annual ACM symposium on User interface software and technology*, pp. 173-182, 2003.

[Card, et al, 1999] Card, S, K. Mackinlay, J, D. and Schneiderman, B. ‘Readings in information Visualisation; Using vision to think,’ Morgan Kaufmann, 1999.

[Cañas et al. 2003] Cañas, A, J. Coffey, J, W. Carnot, M, J. Feltovich, P. Hoffman, R, R. Feltovich, J. and Novak, J, D. ‘A Summary of Literature Pertaining to the Use of Concept mapping Techniques and Technologies for Education and Performance Support,’ The Institute for Human and Machine Cognition, 2003. Available online at: http://www.ihmc.us/user’s/acanas/Publications/ConceptMapLitReview/IHMC%20Literature%20Review%20on%20Concept%20Mapping.pdf. Last accessed 9th February 2007.

[Cañas et al, 2005], A. J. Cañas, A. J. Carff, R. Hill, G. Carvalho, M. Arguedas, M. Eskridge, T, C. Lott, J. Carvajal, R. ‘Concept maps: Integrating Knowledge and Information Visualisation,’ in Knowledge and Information Visualisation: Searching for Synergies, S.-O. Tergan, and T. Keller, Editors, Springer Lecture Notes in Computer Science, 2005. Available online at: http://cmap.ihmc.us/Publications/ResearchPapers/ConceptMapsIntegratingKnowInfVisual.pdf. Last accessed 14th March, 2007.

[Cappelletti et al, 2004] Cappelletti, A. Gelmini, G. Pianesi, F. Rossi, F. and Zancanaro, M. ‘Enforcing cooperative storytelling: first studies,’ in *Proc. ICALT2004,* IEEE Computer Society, pp. 281-285, 2004.

[Chang et al, 2001] Chang, K. E. Sung, Y. T. and Chen, S. F. 2001. Learning through computer-based Concept mapping with scaffolding Aid. *Journal of Computer Assisted Learning,* 17, 1, pp. 21-33.

[Chen and Davis, 2002] Chen, X. and Davis, J. ‘LumiPoint: Multi-User Laser-Based Interaction on Large Tiled Displays,’ *Displays,* 23*,* 5, pp. 205-211, 2002.

[Chi, Glaser and Farr, 1988] Chi, M, T, H. Glaser, R. and Farr, M, J. ‘The nature of expertise,’ Hillsdale, NJ: Lawrence Erlsbaum Associate, Inc, 1988.

[Chi et al. 1989] Chi, M, T, H Bassok, M. Lewis, M, W. Reimann, P. and Glaser, R. ‘Self-explanations: How students study and use examples in learning to solve problems,’ *Cognitive Science*, 13, pp. 145-182, 1989.

[Chi et al. 1994] Chi, M, T, H. de Leeuw, N. Chiu, M, H. and Lavancher, C. ‘Eliciting self-explanations improves understanding,’ *Cognitive Science*, 18, pp. 439–477, 1994.

[Chickering and Gamson, 1987] Chickering, A. and Z. Gamson. ‘Seven Principals for Good Practice,’ AAHE Bulletin, 39, pp. 3–7, 1987.

[Chin and Brown, 2000] Chin, C. and Brown, D, E. ‘Learning in science: a comparison of deep and surface approaches’ Journal of Research in Science Teaching, 37, pp. 109–138, 2000.

[Chiu et al, 1999] Chiu, C-H. Huang, C-C. Chang, W-T. and Liang, T-H. ‘Interaction Processes in Network Supported Collaborative Concept mapping,’ *ItiCSE, Cracow Poland*, pp. 75-78, 1999.

[Chiu et al 1999] Chiu, C-H. ‘Evaluating system-based strategies for managing conflict in collaborative concept mapping,’ *J. of Computer Assisted Learning*, 20, pp. 124-132, 2004.

[Chou et al, 2001] Chou, P. Grutser, M. Lai, J. Levas, A. McFaddin, S. Pinhanez, C. Viveros, M. Wong, D. and Yoshihama, S. 'BlueSpace: Creating a personalized and context-aware workspace,' *IBM,* 2001.

[Chu et al, 2000] Chu, C-H. Huang, C-C. Chang, W-T. 'The evaluation and influence of interaction in network supported collaborative concept mapping,' *Computers and Education,* 34, pp. 17-25, 2000.

[Chung, et al, 1999] Chung, G, K, W, K. O'Neil, Jr, H, F. Herl, H, E. 'The use of computer-based collaborative knowledge mapping to measure team processes and team outcomes' *Computers in Human Behavior,* 15, pp. 463-493, 1999.

[Church and Meadow, 1986] Church, R, B. and Goldin-Meadow, S. 'The mismatch between gesture and speech as an index of transitional knowledge,' *Cognition,* 23, pp. 43-71, 1986.

[Cohen and Lotan, 1997] Cohen, E, G. and Lotan, R, A. 'Working for equity in heterogeneous classrooms: Sociological theory in practice,' New York: Teachers College Press, 1997.

[Chin and Brown, 2000] Chin, C. and Brown, D, E. 'Learning in Science: A Comparison of Deep and Surface Approaches,' *Journal of Research in Science Teaching,* 37, 2, pp. 109-138, 2000.

[Chow, 2009] Chow, Y.W. '3D Spatial Interaction with the Wii Remote for Head-Mounted Display Virtual Reality,' *World Academy of Science, Engineering and Technology, 50*, pp. 377-383, 2009.

[Clements, 1999] Clements, D, H. 'Concrete' manipulatives, concrete ideas," *Contemporary Issues in Early Childhood,* 11, pp. 45-60, 1999. Available online at: http://www.wwwords.co.uk/pdf/viewpdf.asp?j=ciecandvol=1andissue=1andyear=2000 andarticle=clementsand id=129.234.4.1. Last accessed 15th March, 2007.

[Czerniak and Haney, 1998.] Czerniak, C, M. and Haney, J, J. 'The Effect of Collaborative Concept mapping on Elementary Preservice Teachers' Anxiety, Efficacy, and Achievement in Physical Science,' *J. of Science Teacher Education,* 9, 4, pp. 303-320, 1998.

[Darmofal et al, 2002] Darmofal, D, L. Soderholm, D, H. and Brodeur, D, R. 'Using Concept maps and Concept Questions to Enhance Conceptual Understanding,' *IEEE,* 2002.

[Davis, 1993] Davis, B, G. 'Tools for Teaching', Jossey-Bass, 1993.

[Deligiannidi et al, 2008] L. Deligiannidis and J. Larkin, "Navigating inexpensively and wirelessly," in *Proc. of Human System Interaction (HSI'08),* Krakow, Poland, pp. 165–169, 2008.

[Depover 2004] Depover, C. Quintin, J-J. and De Lievre, B. in 'Collaborative Concept mapping in Education: Major Research Trends,' Proc. Of the second Int. Conference on Concept mapping, Costa Rica, 2006.

[Dillon et al, 2005] Dillon, K, M. Hillis, D, W. and Talbot, P, J. 'Knowledge Visualisation: Redesigning the Human-Computer Interface,' *Technology Review Journal,* Spring/Summer, 2005.

[Dimicco et al. 2004] Dimicco, J, M. Pandolfo, A. and Bender, W. 'Influencing group participation with a shared display,' in *Proc. CSCW,* pp. 614-623, 2004.

[Diseth and Martinsen, 2003] Diseth, A. and Martinsen, O. 'Approaches to Learning, Cognitive Style, and Motives as Predictors of Academic Achievement,' *Educational Psychology,* 23, 2, pp. 195-207, 2003.

[Do-Lenh et al, 2009] Do-Lenh, S. Kaplan, F. Dillenbourg, P. 'Paper-based Concept map: the effects of Tabletop on an Expressive Collaborative Learning Task,' *People and Computers,* XXIII – Celebrating people and technology, pp. 149-158, 2009.

[Doolittle, 1999] Doolittle, P. 'Constructivism and online education,' in *Online Conference on Teaching Online in Higher Education,* Fort Wayne, USA, 1999.

[Dourish, 2001] Dourish, P. 'Where the Action is: the Foundations of Embodied Interaction'. MIT Press, Cambridge, Mass. USA, 2001.

[Driver et al, 1994] Driver, R. Asoko, H. Leach, J. Mortimer, E. and Scott, P. 'Constructing Scientific Knowledge in the Classroom,' *Educational researcher,* 23, 7, pp. 5-12, 1994.

[Dudfield et al, 2001] Dudfield, H. J. Macklin, C. Fearnley, R. Simpson, A. and Hall, P. 'Big is better? Human factors issues of large-screen displays with military command teams,' in *Proceedings of People in Control*, pp. 304–309, 2001.

[Duit and Treagust, 2003] Duit, R. and Treagust, D, F. 'Conceptual change: a powerful framework for improving science teaching and learning,' *International Journal of Science Education,* 25, 6, pp. 671-688, 2003.

[Durling and Schick, 1976] Durling, R. and Schick, C. 'Concept attainment by pairs and individuals as a function of vocalization,' *Journal of Education Psychology,* 68, pp. 83-91, 1976.

[Edmondson and Novak, 1993] Edmondson K. Novak J. D. 'The interplay of epistemological views, learning strategies, and attitudes of college students.' *J Res Sci Teach.* 30, 6 pp. 547–559, 1993.

[Edmondson and Smith, 1996] Edmondson, K. M. and Smith, D, F. 'Concept mapping to facilitate veterinary students' understanding of fluid and electrolyte disorders,' Paper presented at the American Educational Research Association, New York, NY, April 8-12, 1996.

[Eisobu, and Soyibu, 1995] Eseiobu, G. O. and Soyibu, K. 'Effects of Concept and Vee Mappings under Three Learning Modes on Students' Cognitive Achievement in Ecology and Genetics,' *J. of Research in Science Teaching, 32,* 9, pp. 971-995, 1995.

[Ellis and Fisher, 1975] Ellis, D. and Fisher, B. 'Phases of conflict in small group development: a markov analysis,' *Human Communication Research*, 1, pp. 195-212, 1975.

[Elrod et al, 1992] Elrod, S. Bruce, R. Gold, R. Goldberg, D. Halasz, F. Janssen, W. Lee, D. McCall, K. Pederson, E. Pier, K. Tang, J. and Welch, B. 'Liveboard: A large interactive display supporting group meetings, presentations and remote collaboration,' *Proceedings of CHI 1992,* pp. 599-607, 1992.

[Entwistle and Waterston, 1988] Entwistle, N. and Waterston, S. 'Approaches to studying and levels of processing in University students,' *British Journal of Educational Psychology,* 58, pp. 258-265, 1988.

[Eppler and Burkhard, 2004] Eppler, M, J. and Burkhard, R, A. 'Knowledge Visualisation: Towards a New Discipline and its Fields of Application,' 2004. Available online at http://en.scientificcommons.org/12749217. Last accessed 24th May, 2007.

[Ericson, and Rogers, 1973] Ericson, P. M. and Rogers, L. E. 'New procedures for analysing relational communication,' Family Process, 1973.

[Fabri, et al. 2002] Fabri, M. Moore, D.J. Hobbs, D.J. 'Expressive Agents: Non-verbal Communication in Collaborative Virtual Environments,' in *Proceedings of Autonomous Agents and Multi-Agent Systems Embodied Conversational Agents*, July 2002, Bologna, Italy.

[Fails et al, 2005] Fails, J, A. Druin, A. Guha, M, L. Chipma, G. Simms, S. and Churaman, W. 'Child's play: a comparison of desktop and physical interactive environments,' in Proc. Of *IDC* 2005, pp. 48-55, 2005.

[Farrand et al. 2002] Farrand, P. Hussain, F. and Hennessy, E. 'The efficacy of the 'mind map' study technique,' *Medical Education,* 36, pp. 426-431, 2002.
Available online at:
http://www.blackwellsynergy.com/links/doi/10.1046%2Fj.13652923.2002.01205.x.
Last accessed 4th February 2007.

[Fernaeus and Tholander, 2005] Fernaeus, Y. and Tholander, J. 'Looking at the computer but doing it on land': children's interactions in a tangible programming space,' in Proc of *HCI* 2005, pp. 3-18, 2005.

[Fischer and Mandl, 2001] Fischer, F. and Mandl, H. 'Facilitating the construction of shared knowledge with graphical representation tools in face-to-face and computer-mediated scenarios'. In P. Dillenbourg, A. Eurelings and Hakkarainen, K. Eds. *Proceedings of euro-CSCL 2001* Maastricht, NL, March 2001 pp. 230-236, Maastricht: McLuhan Institute.

[Fleck et al, 2009] Fleck, R. Rogers, Y. Yuill, N. Marshall, P. Carr, A. Rick, J. and Bonnett, V. 'Actions Speak Loudly with Words: Unpacking Collaboration Around the Table,' *ITS'09,* November 23-25, 2009, Banff, Alberta, Canada, 2009.

[Fraser, 1993] Fraser, K, M. 'Theory based use of concept mapping in organization development: creating shared understanding as a basis for the cooperative design of work changes and changes in working relationships. Unpublished doctoral dissertation,' 1993.

[Freeman, 2004] Freeman, L. 'The power and benefits of concept mapping: measuring use, usefulness, ease of use, and satisfaction.' *INT. J. SCI. EDUC,* 26, 2, pp. 151-169, 2004.

[Garrison, 1990] Garrison, D, R. 'An analysis and evaluation of audio teleconferencing to facilitate education at a distance,' *The American Journal of Distance Education,* 4, 3, pp. 13-24.

[Gaver, 1996] Gaver, W. '*Situating Action III: Affordances for Interaction: The Social is Material for Design,' Ecological Psychology*, 8, pp. 111-130, 1996.
[Goldsmith, et al, 1991] Goldsmith, T. E. Johnson, P. J. and Acton, W, H. 'Assessing structural knowledge'. *Journal of Educational Psychology, 83*, 1, pp. 88-96, 1991.

[Golightly and Gilmore, 1997] Golightly, D. and Gilmore, D, J. 'Breaking the rules of direct manipulation,' *Proceedings of the Human-Computer Interaction* – Interact '97, Chapman and Hall, pp. 156-163, 1997.

[Gorra et al, 2008] Gorra, A, Harrison, G, Munn, A, 'Supporting faculty in the adoption of a synoptic teaching and learning approach: a case study from the UK, *In: International Society for the Scholarship of Teaching and Learning 2008 Conference*, Edmonton, Canada, 16-19 October 2008.

[Gruimbretiere et al, 2001] Gruimbretiere, F. Stone, M. Winograd, T. 'Fluid interaction with High-resolution Wall-size Displays,' *Proceedings of UIST 2001,* 2001.

[Gutwin and Greenberg, 2002] Gutwin, C. and Greenberg, S, A. 'A descriptive framework of workspaces awareness for real-time groupware,' *Computer Supported Cooperative Work, 11,* pp. 411-446, 2002.

[Ha et al, 2006] Ha, V. Inkpen, K. M. Mandryk, and Whalen. T. 'Direct Intentions: the effects of input devices on collaboration around a tabletop display,' Horizontal Interactive Human-Computer Systems, 2006.

[Hackman, and Walker, 1990] Hackman, M, Z. Walker, K, B. 'Instructional communication in the televised classroom: The effects of system design and teacher immediacy on student learning and satisfaction,' *Communication Education,* 39, pp. 196-206, 1990.

[Hake, 1997] Hake, R. 'Interactive-Engagement vs. Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses,' *American Journal of Physics*, 66, 1, 1997.

[Harris et al, 2009] Harris, A. Rick, J. Bonnett, V.J. Yuill, N. Fleck, R. Marshall, P. And Rogers, Y. 'Around the table: Are multiple-touch surfaces better than single-touch for children's collaborative interactions,' in Proc. *CSCL09,* pp 335-344, 2009.

[Hay et al, 2008] Hay, S. Newman, J and Harle, R. 'Optical tracking using commodity hardware,' in *IEEE International Symposium on Mixed and Augmented Reality,* pp. 159-160, 2008.

[Heikkila and Lonka, 2006] Heikkila, A. and Lonka, K. 'Studying in Higher Education: students' approaches to learning, self regulation, and cognitive strategies,' *Studies in Higher Education,* 31, 1, pp. 99-117, 2006.

[Helman and Horswill 2002] Helman, M. and Horswill, S. 'Does the introduction of non-traditional teaching techniques improve psychology undergraduates' performance in statistics?' *Psychology Learning and Teaching*, 21, pp. 12-16, 2002.

[Higgins et al, 2009] Higgins, S. Elliot, J. Burd, E. L. Hatch, A. Kyaw, P. and Mercier, E. 'Multi-touch desks for learning: developing pedagogy through technology,' European Learning and Instruction Conference. Amsterdam, Netherlands.

[Hillman, Willis, and Gunawardena, 1994] Hillman, D, C. Willis, D, J. and Gunawardena, C, N. 'Learner-Interface interaction in distance education: An extension of contemporary models and strategies for practitioners,' *The American Journal of Distance Education,* 8, 2, pp. 30-42, 1994.

[Holley, and Dansereau, 1984] Holley, C, D. and Dansereau, D. 'Networking: The technique and the empirical evidence,' in Holley, C, D. and Dansereau, D. Eds. *Spatial Learning Strategies: Techniques, Applications and Related Issues,* pp. 81-108, San Diego: Academic Press, 1984.

[Holmquist et al, 1999] Homquist, L, E. Redstrom, J. and Ljungstrand, P. 'Token-Based Access to Digital Information,' *Proceedings of First International Symposium on Handheld and Ubiquitous Computing,* Springer-Verlag, pp. 234-245, 1999.

[Hornecker, 2005] Hornecker, E.A. 'Design Theme for Tangible Interaction: Embodied Facilitation' in *ECSCW 2005,* Kluwer Academic Publishers, pp/ 23-43, 2005.

[Hornecker et al, 2008] Hornecker, E. Marshall, P. Dalton, N.S. and Rogers, Y. 'Collaboration and interference: awareness with mice or touch input,' *CSCW '08: Proceedings of the ACM 2008 conference on Computer supported cooperative work,* pp.167-176, 2008.

[Hornecker and Buur, 2006] Hornecker, E. and Buur, J. 'Getting a grip on tangible interaction: a framework on physical space and social interaction', *In Proc. CHI 2006*, ACM Press, pp. 437-446, 2006.

[Horton et al, 1993] Horton, P, B. McConney, A, A. Gallo, M. Woods, A. L. Senn, G. J. and Hamelin, D. 'An investigation of the effectiveness of concept mapping as an instructional tool.' *Science Education,* 771, pp. 95-111.

[Hourcade and Bederson. 1999]. Hourcade, J. P. and Bederson. 'Architecture and Implementation of a Java Package for Multiple Input Devices MID.' Tech Report HCIL-99-08, CS-TR-4018, UMIACS-TR-99-26, Computer Science Department, University of Maryland, College Park, MD.

[Huang, and Olson and Olson, 2002] Huang, W. Olson, J, S. and Olson, G, M. 'Camera angle affects dominance in video-mediated communication' *In Proc. CHI,* pp. 716-717, 2002.

[Huxham, 2005] Huxham, M. 'Learning in Lecture – Do interactive windows help?' *Active Learning in Higher Education the Journal of the Institute for Learning and Teaching,* 6, 1, p17-31, 2005.

[Inkpen et al. 2005] Inkpen, K. McGrenere, J. Booth, K, S. and Klawe, M. 'The effect of turn-taking protocols on children's learning in a mouse-driven collaborative environments,' In *Proc. HCI International*, 2005.

[Ishii, 1994] Ishii, H. Kobayashi, M. and Arita, K. 'Iterative design of seamless collaboration media,' *CACM*, 378, 1994.

[Izadi et al, 2003] Izadi, S. Brignull, H. Rodden, T. Rogers, Y. and Underwood, M. 'Dynamo: A Public Interactive Surface Supporting the Cooperative Sharing and Exchange of Media,' *Proceedings of UIST,* pp. 159-168, 2003.

[Jacobson, and Levin, 1995] Jacobson, M.J. and Levin, J.A. 'Conceptual frameworks for network learning environments: Constructing personal and shared knowledge spaces.' *Journal of Educational Telecommunications,* 1, 4, pp. 367-388

[Johanson et al, 2002] Johanson, B. Fox, A. and Winograd, T. 'The Interactive Workspaces Project: Experiences with Ubiquitous Computing Rooms,' *IEEE Pervasive Computing,* pp. 67-74, 2002. Available online at: http://www.realtechsupport.org/UB/AmI/texts/Winograd_Environments_2002.pdf. Last accessed January 2007.

[Johanson et al, 2009] Johanson, B. Fox, A. And Winograd, T. 'The Stanford Interactive Workspaces Project,' Lahlou, S. (Ed.) *Designing User Friendly Augmented Work Environments: From Meeting Rooms to Digital Collaborative Spaces,* Springer-Verlag, pp. 2009.

[Johnson and Johnson, et al, 1991] Johnson, D, W. Johnson, R. Ortiz, A. and Stanne, M. 'Impact of positive goal and resource interdependence on achievement, interaction, and attitudes,' *Journal of General Psychology,* 118, pp. 341-347, 1991.

[Johnson and Johnson and Smith, 1998] Johnson, D, W. Johnson, D, T. and Smith, K, A. 'Active Learning: Cooperation in the College Classroom', 2nd ed. Edina, Minn: Interaction Book Company, 1998.

[Johnson and Johnson, 2004] Johnson, D, W. and Johnson F, P. 'Joining Together: Group Theory and Group Skills' 8th edition, Allyn and Bacon, 2004, 0-205-36740-2.

[Jonassen et al, 1993] Jonassen, D. and Wang, S. 'Acquiring structural knowledge from semantically structured hypertext,' *Journal of Computer-Based Instruction*, 201, pp. 1-8, 1993.

[Jonassen, 2000] Jonassen, D, H. 'Computers as mindtools for schools: Engaging critical thinking,' Prentice-Hall, 2000, in Kim, B. Yang, C-c. and Tsai, I-C. 'Review of Computer-Mediated Collaborative Concept mapping: Implication [sic] for Future Research,' Computer Support for Collaborative Learning Proceedings of the 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years! Taipei, Taiwan, pp. 291-295, 2005, Q-8058-5782-6. Available online at: http://delivery.acm.org/10.1145/1150000/1149330/p291kim.pdf?key1=1149330andkey2=6681472811andcoll=GUIDEanddl=GUIDEandCFID=26543094andCFTOKEN=25198375. Last accessed, 19th February, 2007.

[Kember, 1996] Kember, D. 'The intention to both memorise and understand: Another approach to learning?' *Higher Education,* 31: pp. 341-354, 1996.
[Kendon, 2004]. Kendon, A. *Gesture: Visible Action as Utterance*: Cambridge University Press.

[Kerawalla et al, 2008] Kerawalla, L. Pearce, D. Yuill, N. Luckin, R. And Harris, A. 'I'm keeping those there, are you? The role of a new user interface paradigm-separate control of shared space (scoss)- in the collaborative decision making process,' *Computing Education*, 50 (1), pp. 19-206, 2008.

[Khamesan and Hammond, 2004] Khamesan, A. and Hammond, N. 'Synchronous collaborative concept mapping via ICT: Learning effectiveness and personal and interpersonal awareness,' 2004, in Cañas, A, J. Novak, J, D. and Gonzalez, F, M. Eds. *Proceedings of the First International Conference on Concept mapping, Pamplona, Spain, 2004*. Pamplona, Spain: Universidad Publica de Navarra.

[Khamesan and Hammond, 2005] Khamesan, A. and Hammond, N. 'Learning Effectiveness in On-Line Collaborative Concept mapping via CMC: Comparing Different Mode of Interaction,' in Kommers, P. and Richards, G. Eds. *Proceedings of EDMEDIA2005, Montreal, June 27 to July 2,* pp. 3179-3186, Norfolk, VA: Advancement of Computing in Education AACE, 2005.

[Kim et al. 2005] Kim, B. Yang, C-c. and Tsai, I-C. 'Review of Computer-Mediated Collaborative Concept mapping: Implication [sic] for Future Research,' Computer Support for Collaborative Learning Proceedings of the 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years! Taipei, Taiwan, pp. 291-295, 2005, Q-8058-5782-6, Available online at: http://delivery.acm.org/10.1145/1150000/1149330/p291kim.pdf?key1=1149330andkey2=668472811andcoll=GUIDEanddl=GUIDEandCFID=26543094andCFTOKEN=25198375. Last accessed, 19th February, 2007.

[Kinchin, 2001] Kinchin, I, M. 'If concept mapping is so helpful to learning biology, why aren't we all doing it?' *INT. J. SCI. EDUC.* 23, 12, pp. 1257-1269, 2001.

[Kinchin and Hay, 2000] Kinchin, I, M. and Hay, D, B. 'How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development,' *Educational Research,* 42, 1, pp. 43-57, 2000.

[Kirriemuir and McFarlane, 2004] Kirriemuir, J. and McFarlane, A. 'Literature Review in Games and Learning,' Futurelab, 2004.

[Kirschner et al. 2006] Kirschner, P. A. Sweller, J. and Clark, R, E. 'Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching'. *Educational Psychologist,* 41, 2, pp. 75-86, 2006.

[Klahr et al, 2006] Klahr, D. Triona, L, M. and Williams, C. 'Hands on what? The relative effectiveness of physical vs. virtual materials in an engineering design project by middle school children,' *Journal of Research in Science Teaching,* 2006. Available online at http://www.psy.cmu.edu/faculty/klahr/personal/pdf/KlahrTrionaand Williams07.pdf. Last accessed 29th March 2007.

[Klein et al, 2001] Klein, D.C.D. Chung, G.K.W.K. Osmundson, E. Herl, H.E. and O'Neil, H.F. 'Examining the validity of knowledge mapping as a measure of elementary students' scientific understanding,' Los Angeles: National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

[Knapp, M, 1978] Knapp, M, Social intercourse: From greeting to goodbye, Boston: Allyn and Bacon, Inc.

[Knowles et al. 1984] Knowles, M, S. et al. 'Andragogy in Action. Applying modern principals of adult education,' San Francisco: Jossey Bass.

[Koenig, 2010] Koenig, W.A. 'Design and evaluation of novel input devices and interaction techniques for large, high-resolution displays,' Unpublished PhD thesis, 2010.

[Koleva et al, 2003] Koleva, B. Benford, S. Ng, K, H. and Rodden, T. 'A framework for tangible user interfaces,' *Proceedings of the Physical Interaction Workshop on Real World User Interfaces,* Mobile HCI Conference, 2003.

[Kurtenbach and Fitzmaurice, 2005] Kurtenbach, G. and Fitzmaurice, G. 'Applications of large displays,' *IEEE,* 2005, in Ni, T. Schmidt, G, S. Staadt, O, G. Livingston, M. A. Ball, R. and May, R, 'A Survey of Large High-Resolution Display Technologies Techniques and Applications,' 2006.

[Kyaw and Drummond, 2007] Kyaw P, and Drummond S, 'Synoptic learning and assessment: An experience report,' *The 8th Annual Conference of the Higher Education Academy, University of Southampton*, 28th - 30th Aug 2007.

[Laight, 2006] Laight, D, W. 'Attitudes to concept maps as a teaching/learning activity in undergraduate health professional education: influence of preferred approach to learning,' *Medical Teacher,* 28, 2, pp. 64-67, 2006.

[Lapping-Carr et al, 2008] Lapping-Carr, M. Jenkins, O.C. Grollman, D.H. Schowertfeger, J.N. and Hinkle, T.R. 'Wiimote interfaces for lifelong robot learning,' in *Proc.of AAAI Symposium on using AI to Motivate Greater Participation in Computer Science*, Palo Alto, C.A., 2008.

[Lammers and Murphy, 2002] Lammers, W, J. and Murphy, J, J. 'A profile of Teaching Techniques Used in the University Classroom,' *Active Learning in Higher Education,* 3: pp. 54-67, 2002, in Huxham, M. 'Learning in Lecture – Do interactive windows help?' *Active Learning in Higher Education the Journal of the Institute for Learning and Teaching,* 6, 1, pp. 17-31, 2005.

[LaViola et al. 2004] LaViola, J. Keefe, D. Zeleznik, R. and Acevedo, D. 'Case Studies in Building Custom Input Devices for Virtual Environment Interaction,' In *VR 2004 Workshop: Beyond Glove and Wand Based Interaction*, Chicago, IL, March 2004.

[Ledger, 2003] Ledger, A. F. 'The Effects of Collaborative Concept mapping on the Achievement, Science Self-efficacy and Attitude Toward Science of Female Eighth Grade Students,' University of Massachusetts, Lowell, 2003.

[Lee et al, 2006] Lee, H. Plass, J, L. Homer, B, D. 'Optimizing Cognitive Load for Learning From Computer-Based Science Simulations,' Journal of Educational Psychology, 98, 4, pp. 902-913, 2006.
Available online at:
http://create.alt.ed.nyu.edu/create/files/JEP_Lee_Plass_Homer.pdf. Last accessed 15th March, 2007.

[Lee et al, 2007] Lee, J. Lee, J. Kim, H.S. and Kim, J.I. 'Gesture-Based Interactions on Multiple Large Displays with a Tabletop Interface,' *Lecture Notes in Human-Computer Science,* Vol. 4555, pp. 936-942, 2007.

[Lee et al, 2008] Lee, H.J. Kim, H. Gupta, G. and Mazalek, A. 'WiiArts: Creating collaborative art experience with WiiRemote Interaction,' in *Proc. Of the 2nd International Conference on Tangible and Embedded Interaction (TEI'08),* Bonn, Germany, pp. 33–36, 2008.

[Lee and Brophy, 1996] Lee, O. and Brophy, J. 'Motivational patterns observed in sixth grade science classrooms,' *Journal of Research in Science Teaching*, 33, pp. 303–318, 1996.

[Leeds Met, 2011] Leeds Metropolitan University, 2011. Available online at: http://www.leedsmet.ac.uk/inn/alic/synoptic.htm. Last accessed December, 2011.

[Levisohn, 2007] Levisohn, A. 'The Body as a Medium: Reassessing the Role of Kinesthetic Awareness in Interactive Applications,' In *Proc. MM 2007,* ACM Press, pp.485-488, 2007.

[Lindley, Couteur, and Bianchi-Berthouze, 2008] 'Stirring up Experience through Movement in Game Play: Effects on Engagement and Social Behaviour' CHI 2008, April 5-10, 2008, Florence Italy.

[Long and Ehrmann, 2005] Long, P, D. and Ehrmann, S, C. 'Future of the Learning Space: breaking Out of the Box,' *EDUCAUSE review,* 40, 4, pp. 42-58, 2005. Available online at: http://icampus.mit.edu/news/articles/PhilLong-Educause-JulAug05-Future.pdf. Last accessed 19th March 2007.

[Lord, 2000]Lord, C. Risi, S. Lambrecht, L. Cook, E.H. Lenventhal, B.L. DiLavore, P.S. et al, 'The Autism Diagnostic Observation Schedule-Generic: A standard measure of social and communication deficits associated with the spectrum of autism,' *Journal of Autism and Developmental Disorders*, 30, pp. 205–223, 2000.

[Luebke et al, 2002] Luebke, W. Richmond, M. McCrickard, D, S. 'Collaborative Environments Supported By Large-screen Displays,' *CSCW.02,* November pp. 16.20, 2002.
Available online at, http://people.cs.vt.edu/~mccricks/papers/lrm02.pdf. Last accessed 27th May 2007.

[Malik, et al, 2005] Malik, S. Ranjan, A. and Balakrishnan, R. 'Interacting with large displays from a distance with vision-tracked multi-finger gestural input,' *in Proc. UIST*, pp. 43-52, 2005.

[Manches et al, 2009] Manches, A. O'Malley, C. and Benford, S. 'Physical manipulation: evaluating the potential for tangible designs,' *in TEI '09: Proceedings of the 3rd International Conference on Tangible and Embodied Interaction,* pp 77-84, ACM, 2009.

[Marshall et al, 2003] Marshall, P. Price, S. and Rogers, Y. 'Conceptualising tangibles to support learning,' *ACM,* 2003.

[Marshall et al, 2006] Marshall, P. Rogers, Y. Hornecker, E. 'Are Tangible Interfaces Really Any Better Than Other Kinds of Interfaces?' Pervasive Interaction Lab, Open University, 2006.

[Marshall et al, 2007] Marshall, P. 'Do tangible interfaces enhance learning?' TEI'07 February 15-17, 2007, Baton Rouge, Louisiana, USA.

[Marshall et al, 2008] Marshall, P. Hornecker, E. Morris, R. Sheep Dalton, N. and Rogers, Y. 'When the fingers do the talking: A study of group participation with varying constraints to a tabletop interface,' in *3rd IEE International Workshop on Horizontal Interactive Human Computer Systems*, pp. 33-40, 2008.

[Marshall et al, 2009] Marshall, P. Fleck, R. Harris, A. Rick, J. Hornecker, E. Rogers, Y. Yuill, N. and Dalton, N.S. 'Fighting for control: children's embodied interactions when using physical and digital representations,' in *Proc. CHI 2009, ACM,* pp.2149-2152, 2009.

[Marton and Saljo, 1976] Marton, F. and Saljo, R. ‘On qualitative differences in learning. I: Outcome and process’, *British Journal of Educational Psychology*, 46: pp. 4-11, 1976.

[McAleese, Grabinger, and Fisher, 1999] McAleese, R. Grabinger, S. and Fisher, K. ‘The Knowledge Arena: a learning environment that underpins concept mapping’ Paper presented at the AERA ´99 conference.

[McClure et al, 1999] McClure, J.R., Sonak, B., & Suen, H.K. ‘Concept map assessment of classroom learning: Reliability, validity, and logistical practicality,’ *Journal of Research in Science Teaching*, 36, pp. 475–492, 1999.

[McDonald, and Stevenson, 1998] McDonald, S. and Stevenson, R.J. ‘Navigation in hyperspace: An evaluation of the effects of navigational tools and subject matter expertise on browsing and information retrieval in hypertext,’ *Interacting with Computers 10*, pp. 129-142, 1998.

[Mercier, Goldman, Booker, 2009] Mercier, E.M. Goldman, S. and Booker, A. ‘Focusing on Process: Evidence and Ideas to Promote Learning Through the Collaborative Design Process,’ in *Educating Learning Technology Designers: guiding and inspiring creators of innovative educational tools,* DiGiano, C. Goldman, S. and Chorost, M. New York: Routledge. pp. 36-61.

[Miell, and MacDonald, 2000] Miell, D. and MacDonald, R, ‘Children's creative collaborations: The importance of friendship when working together on a musical composition,’ *Social Development*, 93, pp. 348-369.

[Milne, 2007] Milne, A, J. ‘Entering the Interaction Age Today: Implementing a Future Vision for Campus Learning Spaces…’ *EDUCAUSE review,* 42, 1, pp. 13-31, 2007. Available online at: http://www.educause.edu/ir/library/pdf/erm0710.pdf. Last accessed 19th March 2007.

[Minsky, 1977] Minsky, M. 'Frame-system theory', in Johnson-Laird, P, N. and Watson, P, C. Eds. *Thinking-Readings* in *Cognitive Science.* Cambridge: Cambridge University Press, pp. 355-376, 1977.

[MIT, 2007] MIT, Tangible Media Group, 2007.
Available online at http://tangible.media.mit.edu/projects/. Last accessed 19th June 2007.

[Moran et al, 1997] Moore, M. ‘Pen-based interaction techniques for organizing material on an electronic whiteboard,’ *In Proc, UIST*, pp. 127-136, 1997.

[Moore, 1989] Moore, M. ‘Editorial: Three types of interaction,’ *The American Journal of Distance Education,* 3, 2, pp. 1-7, 1989.

[Moreland, Dansereau, and Chmielewski, 1997] Moreland, J. L. Dansereau, D. F. and Chmielewski, T. L. 1997. Recall of descriptive information: The roles of presentation format, annotation strategy, and individual differences. *Contemporary Educational Psychology, 22*4, pp. 521-533.

[Morris, 1979] Morris, D. Collett, P. Marsh, P. and O’Shaughnessy, M. ‘Gestures,’ Stein and Day, New York, 1979.

[Muller-Tomfelde and Schremmer, 2008] Muller-Tomfelde, C and Schremmer, C. ‘Touchers and mousers: commonalities and differences in co-located collaboration with multiple input devices,’ *CHI 2008: Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems,* pp. 1149-1152, 2008.

[Myers, 1991] Myers, M. Cooperative Learning 11, 4, July, 1991.

[Myers, 2000] Myers, B. ‘Using multiple devices simultaneously for display and control,’ *IEEE Personal Communications*, 75, 2000.

[Nacenta et al, 2007] Nacenta, M.A. Pinelle, D. Stuckel, D. and Gutwin, C. ‘The effects of interaction technique on coordination on in tabletop groupware,’ *GI ’07: Proceedings of Graphics Interface,* pp. 191-198, 2007.

[Newell, 1977] Newell, A. 'On the analysis of human problem solving', in Johnson-Laird, P, N. and Watson, P, C. Eds. *Thinking - Readings in Cognitive Science.* Cambridge: Cambridge University Press, pp. 46-61, 1977.

[Ni et al, 2006] Ni, T. Schmidt, G, S. Staadt, O, G. Livingston, M, A. Ball, R. and May, R. ‘A Survey of Large High-Resolution Display Technologies, Techniques, and Applications,’ *Virtual Reality*, 2006.
Available online at http://infovis.cs.vt.edu/papers/vr06-survey.pdf. Last accessed 5th June 2007.

[Nicoll et al, 2001] Nicoll, G. Francisco, J. and Nakhleh, M, B. ‘An Investigation of the value of using Concept maps in general chemistry,’ *Journal of Chemical Education, 78*8, pp. 1111-1117, 2001.

[Nilsson, R. M. and Mayer, R. E. 2002] Nilsson, R. M. and Mayer, R. E. ‘The effects of graphic organizers giving cues to the structure of a hypertext document on user’s' navigation strategies and performance. *International Journal of Human-Computer Studies*, 571, pp. 1-26.

[Nintendo, 2007/2008]. ‘Wii controllers’. Available online at
http://www.nintendo.com/wii/what/controllers. Last accessed 5th June, 2008

[Norman and Spohrer, 1996] Norman, D, A. and Spohrer, J C. ‘Learner Centred Education’, *Communications of the ACM*, 39, 4: pp. 24-27, 1996.

[Novak, 1979] Novak, J. 'Applying psychology and philosophy to the improvement of laboratory teaching', *The American Biology Teacher,* 41, 8, pp. 466-470, 1979.

[Novak, 1985] Novak, J, D. 'Meta learning and meta knowledge strategies to help students learn how to learn', in West. L, H, T. and Pines, A, L. Eds. *Cognitive Structure* and *Conceptual Change.* Orlando: Academic Press, pp. 189-209, 1985.

[Novak, 1998] Novak, J. Learning, creating and using knowledge. Concept maps as facilitative tools in schools and in corporations. London: Lawrence Erlbaum, 1998.

[Novak, 2002] Novak, J, D. ‘Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies Leading to Empowerment of Learners,’ *Science Education*, 86, 4, pp. 548-71, 2002.

[Novak, 2003] Novak, J, D. ‘The Promise of New Ideas and New technology for Improving Teaching and Learning,’ *Cell Biology Education,* 2, pp. 122-232, 2003.

[Novak, 2005] Novak, J, D. ‘Results and Implications of a 12-Year Longitudinal Study of Science Concept Learning,’ *Research in Science Education*, 35, 1, pp. 23-40, Mar 2005.

[Novak and Cañas, 2006a] Novak, J, D. and Cañas, A, J. ‘The origins of the Concept mapping Tool and the Continuing Evolution of the Tool,’ *Information Visualisation,* 5, 3, pp. 175-184, 2006.

[Novak and Cañas, 2006b] Novak, J, D. and Cañas, A, J. ‘The Theory Underlying Concept maps and How to Construct Them’, Technical Report IHMC CmapTools, Florida Institute for Human and Machine Cognition, 2006. Available online at: http://depts.washington.edu/biology/hhmi/conceptmaps/Novak%20et.al.%202006.pdf Last accessed 7th June 2007.

[Novak and Gowin, 1984] Novak, J, D. and Gowin, D, B. ‘Learning how to learn,’ Cambridge University Press, 1984, 0-52131-926-9.

[Novak, Gowin and Johansen, 1983] Novak, J.D. Gowin, D, B. and Johansen, G, T. ‘The use of concept mapping and knowledge vee mapping with junior high school science students', *Science Education,* 67, 5, pp. 625-645, 1983.

[Oh and Stuerzlinger, 2002] Oh, J. Y. Stuerzlinger, W. ‘Laser pointers as Collaborative Pointing Devices,’ *Graphics Interface, 2002,* Eds. Stuerzlinger, McCool, and Peters, pp.141-149, 2002.

[Okebukola, 1992] Okebukola, P, A. ‘Can Good Concept mappers be Good Problem Solvers in Science?’ *Research in Science and Technological Education, 10*2, pp. 153- 170, 1992.

[Okebukola, 1988] Okebukola, P. A. and Jegede, O, J. ‘Cognitive preference and learning mode as determinants of meaningful learning through concept mapping,’ *Science Education,* 72 4, pp. 489-500, 1988.

[Olsen and Nielsen, 2001] Olsen, D. and Nielsen, T. ‘Laser pointer interaction,’ In *CHI*, 2001.

[Olson and Olson, 2001] Olson, J, S. and Olson, G, M. ‘Distance matters,’ *Human Computer Interaction*, 15, pp. 139-179, 2001.
[O’Malley, 2004] O’Malley, C. and Fraser, D, S. ‘Literature Review in Learning with Tangible Technologies, Futurelab, 2004.

[Pankratius, 1990] Pankratius, W, J. ‘Building an organized knowledge base: concept mapping and achievement in secondary school physics,’ *Journal of Research in Science Teaching, 27*4, pp. 315-333, 1990.

[Pankratius and Keith, 1987] Pankratius, W, J. and Keith, T, M. ‘Building an Organized Knowledge Base: Concept mapping in Secondary School Science,’ Paper presented at the Annual Meeting of the National Science Teachers Association, Washington, DC, 1987.

[Panitz, 1996] Panitz, T. ‘A Definition of Collaborative vs. Cooperative Learning’, deliberations, London Metropolitan University, 2005. Available online at: http://www.londonmet.ac.uk/deliberations/collaborative-learning/panitz-paper.cfm. Last accessed 7th June 2007.

[Pask, 1976a] Pask, G. ‘Conversation Theory - Applications in Education and Epistemology,’ Amsterdam: Elsevier, 1976.

[Pask, 1976b] Pask, G. 'Conversational techniques in the study and practice of education', *British Journal of Educational Psychology,* 46, 1, pp. 12-25, 1976.

[Pavlovych and Stuerzlinger, 2008] ‘Effect of Screen Configuration and Interaction Devices in Shared Display Groupware,’ *HCC ’08, October 31, 2008, Vancouver, British Columbia, Canada, ACM*, pp. 49-56, 2008.

[Pelling et al, 2009] Pelling, C. Sko, T. Gardner, H.J. ‘Be Careful How You Point That Thing: Wiimote Aiming For Large Displays,’ OZCHI ’09, Nov 23-27, 2009, Melbourne Australia, 2009.

[Piaget, 1947] Piaget, J. ‘The psychology of intelligence,’ Routledge and Kegan Paul.

[Piaget and Inhelder, 1967] Piaget, J. and B. Inhelder, ‘A Child's Conception of Space’ F. J. Langdon and J. L. Lunzer, Trans. New York: Norton Original work published 1948.

[Piper et al, 2002] Piper, B. Ratti, C. and Ishii, H. ‘Illuminating clay: a 3-D tangible interface for landscape analysis,’ *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems,* CHI’ 02, ACM Press, pp. 355-362.

[Piper et al, 2009] Piper, A.M. and Holland, J.D. ‘Tabletop displays for small group study: affordances of paper and digital materials,’ in *Proc. CHI 2009,* pp. 1227-1236, 2009.

[Plotnick, 1997] Plotnick, E. ‘Concept mapping: A graphical system for understanding the relationship between concepts,’ ERIC document, June 1997, EDO-IR-97-05. Available online at http://www.ericdigests.org/1998-1/concept.htm. Last accessed 4th June 2007.

[Pompe, 1997] Pompe, C. ‘But they’re Pink!’ – ‘Who cares!’ Popular culture in the primary years,’ in Hilton, M. Ed. Potent fictions: Children’s literacy and the challenge of the popular culture,’ London: Routledge, 1997.

[Prensky, 2005] Prensky, M. ‘Engage Me or Enrage Me: What Today’s Learners Demand,’ *EDUCAUSE review*, 40, 5, pp. 60-64.
Available online at: www.educause.edu/ir/library/pdf/erm0553.pdf. Last accessed 14th February 2007.

[Price et al, 2003] Price, S. Rogers, Y, Scaife, M. Stanton, D. and Neale, H. ‘Using tangibles’ to promote novel forms of playful learning,’ *Interacting with Computers,* 15, pp. 169-185, 2003.

[Ranjan, Birnholtz and Balakrishnan, 2006] Ranjan, A. Birnholtz, J, P. and Balakrishnan, R. ‘An exploratory analysis of partner action and camera control in a video-mediated collaborative task,’ in *Proc. CSCW,* 2006.

[Raskar et al, 1998] Raskar, R. Wetch, G. Cutts, M. Lake, A. Stesin, L. and Fuchs, H. ‘The office of the future: A unified approach to image-based modelling and spatially immersive displays,’ in *Proceedings of SIGGRAPH 1998 International Conference on Computer Graphics and Interactive Techniques*, pp. 179–188, 1998.

[Rebich and Gautier, 2005] Rebich, S. and Gautier, S. 'Concept mapping to Reveal Prior Knowledge and Conceptual Change in A Mock Summit Course on Global Climate Change,' *Journal of Geoscience Education,* 53, 4, pp. 355-365, 2005.

[Redish et al, 1997] Redish, E. J. Saul, and R. Steinberg, 'On the Effectiveness of Active-Engagement Microcomputer-Based Laboratories,' *American Journal of Physics*, 65, 1, 1997, p. 45.

[Rekimoto, 1998] Rekimoto, J. A multiple-device approach for supporting whiteboard based interactions. In *CHI*, 1998.

[Rekimoto, 2002] Rekimoto. J. 'Smartskin: an infrastructure for freehand manipulation on interactive surfaces,' In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'02),* pp. 113-120, 2002.

[Rewey et al. 1989] Rewey, K. Dansereau, D. Dees, S. Skaggs, L. and Pitre, U. 1989. 'Scripted cooperation and knowledge map supplements: Effects on the recall of biological and statistical information,' *Journal of Experimental Education,* 602, pp. 93-107.

[Rick et al, 2009] Rick, J. Harris, A. Marshall, P. Fleck, R. Yule, N. and Rogers, Y. 'Children designing together on a multi-touch tabletop: An analysis of spatial orientation and user interactions,' in *Proc. IDC '09, (2009),* pp 106-114, 2009.

[Ringel, 2001] Ringel, M. Berg, H. Jin, Y. and et al. 'Barehands: Implement-free interaction with a wall-mounted display'. In *CHI Extended Abstracts*, 2001.

[Rockwood, 1995] National Teaching and Learning Forum, 4, 6, 1995, part 1.

[Rogers et al, 2004] Rogers, Y. and Lindley, S. 'Collaborating around vertical and horizontal large interactive displays: which way is best?' *Interacting with Computers,* 16, pp. 1133-1152, 2004.

[Rogers et al, 2002] Rogers, Y. Scaife, M. Gabrielli, S. Smith, H. and Harris, E. 'A conceptual framework for mixed reality environments: Designing novel learning activities for young children,' *Presence,* 11, 6, pp. 677-686, 2002.

[Rogers and Lindley, 2004] Rogers, Y. and Lindley, S. 'Collaborating around vertical and horizontal large interactive displays: which way is best?' *Interacting with Computers,* 16, (6), pp. 1133-1152, 2004.

[Rogers et al, 2009] Rogers, Y. Lim, Y. Hazelwood, W. and Marshall, P. 'Equal opportunities: Do shareable interfaces promote more group participation than single user's displays?' *Human-Computer Interaction*, 24, (2), 2009.

[Roth, 1999] Roth, W-M. 'Authentic School Science: Intellectual Traditions,' in McCormick, R. and Paechter, C. Eds, 'Learning and Knowledge,' Paul Chapman publishing, 1999, 1-85396-427-1.

[Roth, and Roychoudhury, 1992] Roth, W. and Roychoudhury, A. 'The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science.' *Science Education*, 76, 5, pp. 531-557.

[Roth and Roychoudhury, 1993] Roth, W-M. and Roychoudhury, A. 'The Concept map as a Tool for the Collaborative Construction of Knowledge: A Microanalysis of

High School Physics Students,' *Journal of Research in Science Teaching*: 30, 5, pp. 503-534, 1993.

[Roth and Roychoudhury, 1994] Roth, W-M. and Roychoudhury, A. 'Physics students epistemologies and views about knowing and learning,' *Journal of Research in Science Teaching* 31, pp. 5–30, 1994.

[Ruiz-Primo and Shavelson, 1996] Ruiz-Primo, M.A. and Shavelson, R.J. 'Problem and issues in the use of concept maps inn science assessment,' *Journal of Research in Science Teaching,* 33, pp. 569–600, 1996.

[Ruiz-Primo, 2004] Ruiz-Primo, M. A. (2004). 'Examining concept maps as an assessment tool,' in Cañas, A.J. Novak, J. D. and González, F. M. (Eds.), Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology Pamplona, Spain: Universidad Pública de Navarra, pp. 555–562, 2004.

[Rumelhart, 1977] Rumelhart, D, E. 'Introduction to Human Information Processing,' New York: John Wiley and Sons, 1977.

[Ryall et al, 2004] Ryall, K. Forlines, C. Shen, C. and Morris, M.R. 'Exploring the effects of group size and table size on interactions with tabletop shared-display groupware,' *CSCW '04: Proceedings of the 2004 ACM Conference on Computer supported cooperative work,* pp. 604-613, 2004.

[Rye et al, 2002] Rye, J.A. and Rubba, P.A. 'Scoring concept maps: An expert map-based scheme weighted for relationships,' *School Science and Mathematics,* 102, pp. 33–44, 2002.

[Sandberg and Barnard, 1997] Sandberg, J. and Barnard, Y. 'Deep learning is difficult,' *Instructional Science*, Vol. 25, 1, pp. 15-36, 1997.

[Sander et al. 2000] Sander, P. Stevenson, K. King, M. and Coates, D. 'University Students' Expectations of Teaching,' *Studies in Higher Education* 25: pp309-323, 2000, in Huxham, M. 'Learning in Lecture – Do interactive windows help?' *Active Learning in Higher Education the Journal of the Institute for Learning and Teaching,* 6, 1, pp17-31, 2005.

[Santhanam et al. 1998] Santhanam, B. Leach, C. and Dawson, C. 'Concept mapping: how should it be introduced, and is there a long term benefit?' *Higher Education,* 35, pp. 317-328, 1998.
Available online at http://www.jstor.org/view/00181560/sp060197/06x2940b/0. Last accessed 17th March 2007.

[Schlomer, Poppinga, Henze, and Boll 2008] Schlomer, T. Poppinga, B. Henze, N. and, Boll, S. 'Gesture Recognition with a Wii controller' *Proceedings of the Second International Conference on Tangible and Embedded Interaction* TEI'08, Feb 18-20 2008, Bonn, Germany.

[Schou et al, 2007] T. Schou and H.J. Gardner, 'A Wii Remote, a game engine, five sensor bars and a virtual reality theatre,' *in Proc. of Australasian Computer-Human Interaction Conference (OzCHI 2007),* Adelaide, Australia, 2007, pp. 231–234, 2007.

[Scheible, 2006] Scheible, J. Tuulos, V 'Mobile Python – Rapid prototyping of applications on the mobile platform,' John Wiley and Sons, 2006.

[Shizuki et al, 2006] 'Laser pointer interaction techniques using peripheral areas of screens,' in *Proceedings of AVI '06, ACM,* New York, NY, pp.95-98, 2006.

[Sinatra and Pintrich, 2003] Sinatra, G, M. and Pintrich, P, R. 'The role of intentions in conceptual change learning,' in Sinatra, G, M. and Pintrich, P, R. Eds. Intentional conceptual change, pp. 1–18, Mahwah, NJ: Lawrence Erlbaum Associates, Inc, 2003.

[Sizmur and Osborne, 1997] Sizmur, S. and, Osborne, J. 'Learning processes and collaborative concept mapping' *International J. of Science Education,* 19, 10, pp. 1117-1135, 1997.

[Slavin, 1991] Slavin, Robert E. 'Synthesis of Research on Cooperative Learning,' *Educational Leadership* 48 February 1991: pp. 71-82, 1991.

[Smith, 2009] Smith, S. P. and Du'Mont S. 'Measuring the effect of gaming experience on virtual environment navigation tasks,' IEEE Symposium on 3D User Interfaces. IEEE, 3-10.

[Smith et al. 2005] Smith, K, A. Sheppard, S, D. Johnson, D, W. and Johnson, R, T. 'Pedagogies of Engagement: Classroom-Based Practices,' *Journal of Engineering Education,* pp. 1-15, January 2005.

[Smith and MacGregor, 1992] Smith, B, L. and MacGregor, J, T. 'What is Collaborative Learning?' National Centre on Postsecondary Teaching, Learning, and Assessment, Pennsylvania State University, 1992. Available online at:
http://www.biology.washington.edu/HHMI/materials/collab_vs_coop.pdf.
Last accessed 19th March, 2007.

Software for mind-mapping and Information Organisation, 2010, 'Mind Mapping Software'. Available online: http://www.mind-mapping.org/

[Songer and Mintzes, 1994] Songer, C. and Mintzes, J. 'Understanding cellular respiration: An analysis of conceptual change in college biology,' *Journal of Research in Science Teaching*, 316, pp. 621-637, 1994.

[Sowa, 2006] Sowa, J, F. 'Concept mapping,' Technology, Instruction, Cognition and Learning TICL, San Francisco, 2006.

[Sparapani et al, 1997] Sparapani, E, F. Abel, F, J. Stanley, E, E. Edwards, P. and Herbster, D, L. 'Cooperative learning: An investigation of the knowledge and classroom practice of middle grade teachers,' Education, 118, 2, pp. 251-258, 1997.

[Spaulding, 1989] Spaulding, D. T. 'Concept mapping and achievement in high school biology and chemistry,' Unpublished Dissertation, Florida Institute of Technology.

[Stanton, and Neale, 2003] Stanton, D. and Neale, H, R. 'The effects of multiple mice on children's talk and interaction,' *Journal of Computer Assisted Learning*, 19, pp. 229-238, 2003.

[Stasche 2008] Stasche, A. 'Combining Pointing and Gestures,' unpublished master's thesis, 2008. Available online at:

http://hci.uni-konstanz.de/downloads/StascheMasterThesis2008.pdf. Last accessed 14 January, 2009.

[Stewart, Bederson, and Druin, 1999] Stewart J. Bederson B. and Druin A. "Single Display Groupware: A model for Co-present Collaboration", Conference on Human Factors in Computing Systems, CHI 1999, ACM Press.

[Stoyanova, N. and Kommers, 2002] Stoyanova, N. and Kommers, P. 'Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving,' *J. of Interactive Learning Research, 13,* 1/2, pp. 111-133, 2002.

[Strange and Banning, 2001] Strange, C, C. and Banning, J, H. 'Educating by Design: Creating Campus Learning Environments That Work,' San Francisco: Jossey-Bass, 2001.

[Streitz et al, 1999] Streitz, N, N. Holmer, T. Konomi, S. Muller-Tomfelde, C. Reischl, W. Rexroth, P. Seitz, P. and Steinmetz, R. 'I-LAND'.

[Strongman, 1996] Strongman, K. T. 'The psychology of emotion: Theories of emotion in perspective,' Wiley, Chichester, 1996.

[Suthers and Hundhausen, 2001] Suthers, D, D. and Hundhausen, C, D. 'Learning by constructing collaborative representations: An empirical comparison of three alternatives,' in Dillenbourg, P. Eurelings. K and Hakkarainen, K. Eds. *European perspectives on computer-supported collaborative learning, Proceedings of the first European conference on computer-supported collaborative learning,* pp. 577-584, 2001.

[Sutton, 1999] Sutton, L, A. 'Interaction,' Arizona State University, Spring 1999.

[Suzuki and Kato, 1995] Suzuki, H and Kato, H. 'Algoblocks: an open programming language,' in Proc. of *CSCL '95,* pp. 349-355, 1995.

[Svanaes, 2001] Svanaes, D. Context-Aware Technology: A Phenomenological Perspective, *Human Computer Interaction, special issue on context-aware computing*, 16, pp. 379-400, 2001.

[Svensson et al, 2001] Svensson, M.H. Laaksolahti, J and Waern, A. 'Social navigation of food recipes,' in *Proceedings of CHI '01, ACM,* pp. 341-348, 2001.

[Taber, 1994] Taber, K, S. 'Student reaction on being introduced to concept mapping,' *Physics Education*, 29 5, pp. 276-281, 1994

[Tan et al. 2003] Tan, D, S. Gergle, D. Scupelli, P. and Pausch, R. 'With similar viewing angles, larger displays improve spatial performance. In *Proceedings of CHI2003 – the ACM Conference on Human Factors in Computing Systems,* pp. 217-224, 2003.

[Tan et al, 2006] Tan, D, S. Gergle, D. Scupelli, P. and Pausch, R. 'Physically Large Displays Improve Performance on Spatial Tasks,' *ACM Transactions on Computer-Human Interaction,* 13, 1, pp. 71-99, 2006.
Available online at http://www.soc.northwestern.edu/dgergle/pdf/p71-tan.pdf. Last accessed 14 June, 2007.

[Tan et al, 2008] Tan, D.S. Gergle, D. Mandryk, R. Inkpen, K. Kellar, M. Hawkey, K. and Czerwinski, M. 'Using job-shop scheduling tasks for evaluating collocated collaboration,' *personal Ubiquitous Computing,* 12 (3), pp. 255-267, 2008.

[Tang et al, 2006] Tang, A. Tory, M. Po, B. Neumann, P. and Carpendale, S. 'Collaborative coupling over tabletop displays,' in *Proc. CHI 2006, ACM, (2006),* pp 1181-1190, 2006.

[Tani et al, 1994] Tani, M. Masato, H. Kimiya, Y. Koichiro, T. and Futakawa, M. 'Courtyard: Integrating shared overview on a large-screen and per-user detail on individual screens,' in *Proceedings of the CHI 1994 Conference on Human Factors in Computing Systems*, pp. 44–50, 1994.

[Tergan, 2003] Tergan, S-O. 'Concept maps for Managing Individual Knowledge,' p.229- 238, 2003.

[Trowbridge, and Wandersee, 1994] Trowbridge, J, E. and Wandersee, J. 'Identifying critical junctures in learning in a college course on evolution,' *Journal of Research in Science Teaching,* 315, pp. 459-473, 1994.

[Tse and Greenberg, 2004] Tse, E. and Greenberg, S. "Rapidly prototyping Single Display Groupware through the SDGToolkit". In Proceedings of the Fifth Conference on Australasian User interface - Volume 28 Dunedin, New Zealand. A. Cockburn, Ed. ACM International Conference Proceeding Series, 53. Australian Computer Society, Darlinghurst, Australia, pp. 101-110.

[Ullmer and Ishii, 2000] Ullmer, B. and Ishii, H. 'Emerging frameworks for tangible user interfaces,' *IBM Systems Journal*, 393 and 4 pp. 915-931, 2000

[Ullmer and Ishii, 2001] Ullmer, B. and Ishii, H. 'Emerging Frameworks for Tangible User Interfaces,' *Human-Computer Interaction in the New Millennium,* pp. 579-601, 2001.

[Van Boxtel et al, 2000] van Boxtel, C. van der Linden, J. and Kanselaar, G. 'Collaborative learning tasks and the elaboration of conceptual knowledge,' *Learning and instruction, 10*, pp. 311-330, 2000.

[Van Dijk et al. 2001] Van Dijk, L. A. Van Den Berg, G, C. and Van Keulen, H. 'Interactive Lecture in Engineering Education,' *European Journal of Engineering Education,* 26: pp. 15-28, 2001, in Huxham, M. 'Learning in Lecture – Do interactive windows help?' *Active Learning in Higher Education the Journal of the Institute for Learning and Teaching,* 6, 1, pp. 17-31, 2005.

[Vogel and Balakrishnan, 2005] Vogel, D. and Balakrishnan, R. 'Distant freehand pointing and clicking on very large high resolution displays,' in *Proc. UIST,* pp. 33-42, 2005.

[Vogt et al. 2004] Vogt, F. Wong, J. Po, B. Argue, R. Fels, S, S. and Booth, K, S. 'Exploring collaboration with group pointer interaction,' in *Proc. Computer Graphics International,* pp. 636-639, 2004.

[Warburton, 2003] Warburton, K. 'Deep learning and education for sustainability,' *International Journal of Sustainability in Higher Education,* 4, 1, pp. 44-56, 2003.

[Wagner, 1994] Wagner, E, D. 'In support of a functional definition of interaction,' *The American Journal of Distance Education,* 8, 2, pp. 6-29, 1994.

[Wahid, et al, 2003] Wahid, S. Battjer, S. Jain, A. 'Developing Ideas Using Personal and Large-screen Displays,' *ACM-SE Conference '03*, March 7-8, 2003, Savannah, GA.
Available online at, http://people.cs.vt.edu/~mccricks/papers/wbj-acmse03.pdf. Last accessed 18th March 2007.

[Webb, 1982] Webb, N, M. 'Student Interaction and Learning in Small groups,' *Review of Educational Research,* 52, 3, pp. 421-445, 1982.

[White and Gunstone, 1992] White, R. and Gunstone, R. 'Probing Understanding,' The Falmer Press, 1992, 0-75070-048-3.

[Wilson, 1998] Wilson, V., 'Learning How They Learn: A Review of the Literature on Learning Styles,' Muskingum College, 1998.

[Wilson and Shafer, 2003] Wilson, A. and Shafer, S. 'XWand: UI for intelligent spaces' *Proceedings of the conference on Human factors in computing systems*, pp. 545-552, 2003.

[Wittrock, 1994] Wittrock, M.C. 'Generative science teaching', in Fensham, P. Gunstone, R. and R. White Eds. 'The content of science: A constructivist approach to its teaching and learning' pp. 29–38, London: Falmer, 1994.

[Wong, 1993a] Wong, E, D. 'Self-generated analogies as a tool for constructing and evaluating explanations of scientific phenomena,' *Journal of Research in Science Teaching*, 30, pp. 367–380, 1993.

[Wong, 1993b] Wong, E, D. 'Understanding the generative capacity of analogies as a tool for explanation,' *Journal of Research in Science Teaching*, 30, pp. 1259–1272, 1993.

[Yoder and Hochevar, 2005] Yoder, J, D. and Hochevar, C, M. 'Encouraging active learning can improve students' performance on examinations,' *Teaching of Psychology*, 322, pp. 91-95, 2005.

[Zittle, F. J. Jr. 2002] Zittle, F. J. Jr. 'The effect of Web-based concept mapping on analogical transfer,' *Dissertation Abstracts International Section A: Humanities and Social Sciences University Microfilms International, US Jun 2002, 6211-A, 62 11- An* Unpublished Dissertation, University of New Mexico.

[Zuckerman, et al, 2005] Zuckerman, O. Arida, S. and Resnick, M. 'Extending tangible interfaces for education: digital Montessori inspired manipulatives,' in Proc. of *CHI '05*, ACM Press, pp. 859-868, 2005.

9 Appendix

Appendix 1- Experimental hardware

The laptop used to provide the projection of the software was a Sony Vaio VGN-NR10E with the following specifications:

- Processor - Intel Pentium Dual Core T2310 / 1.46 GHz (Dual-Core)
- RAM - 2 GB DDR II SDRAM - 533 MHz (2 x 1 GB)
- Hard Drive - 160 GB - Serial ATA-150 - 5400 rpm
- Operating System - Microsoft Windows Vista Home Premium
- Screen - 15.4" TFT active matrix 1280 x 800 (WXGA)
- Graphics - Intel GMA X3100.

The resolution provided by the laptop was 1280 x 768 pixels.

The projector used was a ViewSonic PJ551 projector and was fixed to the ceiling. The projector had the following specifications:

- Display: Type: 2 cm 3 LCD
- Native: 1024x768 Pixels
- Maximum: 1280x1024 Pixels
- Aspect Ratio: 4:3 (XGA).

The video cameras used to record the experiments are mounted on rails above the students and are fully adjustable throughout the experiment. It is as a result also possible to capture all angles of the participants. Sound is captured by microphones that are also located above the participants and connected to the cameras, which are out of the student's field of vision. The experimenter's position is located at the back of the room by the console which is used to control the video cameras. This location is situated behind and to the left of the subjects so as not to appear within their field of vision. Permissions to use the videos and to participate in the experiment were also provided by all participants and they were free to leave at anytime. Additionally, the experimental design was submitted and passed before the University ethics committee.

Appendix 2- Participant instructions

AIM

The aim of this study is to assess how mode of interaction and input configuration aids or hinders the group construction of conceptual maps.

MATERIALS

You will receive:

- a sheet explaining concept mapping and approaches to concept mapping
- an evaluation of Learning outcomes and knowledge prerequisites questionnaire
- two post-test questionnaires

TASKS

The tasks that you will be asked to complete focus on exploring your domain of knowledge, principally the modules from Computer Systems (Level 1) and Computer Systems II (Level 2), as well as modules from Introduction to Programming/Programming and Data Structures (Level 1) and Programming and Reasoning (Level 2).

You will be asked to complete two concept maps in two conditions in groups of two people.

Condition one – Computer Systems and Computer Systems II

Condition two – Introduction to Programming/Programming and Data Structures and Software Applications

For each condition attempt do the following:

1. Include module content i.e. your interpretation of the syllabus.
2. Consider what you feel you have learnt from the modules and what you expect to learn.
3. Also consider the key skills you have acquired and are expected to have when undertaking or having undertaken the module.

CONTACTS
If you are interested in the results of this study, you may contact Chris Foster (e-mail: c.r.foster@durham.ac.uk)

Appendix 3- Consent form and release of video

Thank you for volunteering to participate in this evaluation of a concept mapping tool.
You will participate in two short experiments, which analyse the creation of concept maps in two environments. The first condition asks you to construct a concept map using a WiiRemote controller as a mouse. The second condition also asks you to create a different concept map, however in this condition the software will be manipulated via gestural interaction. The construction of each concept map, it is expected, will take 30 minutes.

Before undertaking each condition you will be provided with a brief introduction to the software, outlining the functions within it. You will also be able to familiarise yourself with the system for ten minutes before constructing the concept map. At this point, you will also be asked to complete a pre-test questionnaire, which will be used to ascertain how familiar you are with concept mapping tools. After the experiments you will then be provided with a questionnaire which will ask you a series of questions in relation to your use of each tool.

You may also be required to be interviewed about your experiences of WiiConcept and therefore it would be appreciated if you could provide your email address to arrange a time if you consent for this interview to occur.
The researchers appreciate your candid and direct feedback. All information you give us will be kept confidential. Your identity will remain confidential to the extent provided by the law. There are no direct risks to you by participating in this study. The recording of the session will be only reviewed and kept by the researchers. You may withdraw your participation at any time. Thank you.

The participant should complete the whole of this sheet himself/herself

Have you had an opportunity to ask questions and to discuss the study?

[ ] YES [ ] NO

Have you received satisfactory answers to all of your questions?

[ ] YES [ ] NO

Have you received enough information about the study?

[ ] YES [ ] NO

Who have you spoken to?

Prof/Dr/Mr/Mrs/Ms/ ____

Do you understand that you are free to withdraw from the study at any time
and without having to give a reason for withdrawing?

[ ] YES [ ] NO

I have read the procedure described above and I voluntarily agree to participate in this study and have received a copy of this description

Signed ....………................
Date ....…..
(NAME IN BLOCK LETTERS) ....………..............……........

Available for interview………….**YES/NO**………………………

Email address…………………………………………………………………..

Voluntary Release of Video

I grant the researchers (Durham University) permission to use the video of my participation in the use of the concept mapping software WiiConcept. The videos are to be used in scholarly publications and for scholarly purposes. I understand that I am not obligated to complete this part of the consent form and it will in no way impact my participation in the study. I understand that my name and personal information will be kept with strict confidentiality.

Signed ....………................
Date ....…..
(NAME IN BLOCK LETTERS)

Appendix 4- Pre-session questionnaire

ABOUT YOU:

1) Year of Study: [ ] 1st Year [ ] 2nd Year [ ] 3rd Year

2) Handiness: [ ] Left [ ] Right [ ] Ambidextrous

3) Age group: 18-25 26-32 33-39 40-46 47-52 52+ **(please circle your choice)**

4) Gender: [ ] Female [ ] Male

ABOUT YOUR GROUP:

5) Please rate how well you interact with your group partner?

Not well very well

1	2	3	4	5	6	7

COMPUTER AND PERIPHERAL USAGE:

6) Please indicate your typical computer usage: [ ] Daily [ ] Weekly [ ] Monthly [ ] Never

7) Where do you typically use a computer?

[ ] At home [ ] At work [ ] At school [ ] Not applicable

(if NA, go to 8)

i. **Which of the following describes your computer usage? (please choose all those that apply)**

Work [ ] YES [ ] NO

Education [ ] YES [ ] NO

Entertainment [ ] YES [ ] NO

Other, please specify ____

8) How often do you use a computer with other people

i) in the same room?

[ ] Daily [ ] Weekly [ ] Monthly [ ] Never

ii) at the same time?

[ ] Daily [ ] Weekly [ ] Monthly [ ] Never

9) Do you regularly (i.e. at least once a week) use controllers with the following game systems? (please tick all that apply)

[ ] PlayStation 1 [ ] PlayStation 2

[ ] PlayStation 3 [ ] Nintendo Wii

[ ] Xbox 360 [ ] Xbox

[ ] GameCube [ ] Nintendo DS

[ ] PC (Personal Computer)

[ ] Other, please specify ____________________________

10) Have you ever used Nintendo's WiiRemote? [ ] YES [ ] NO

i) **How regularly do you use WiiRemote controllers?**

[ ] Daily [ ] Weekly [ ] Monthly

ii) **Have you used the controllers with any device other than the Nintendo Wii**? [ ] YES [ ] NO

If **YES** please specify ___________________________

ii) **How would you rate your skill level of using gestures? (**In this case a gesture is a physical movement or motion created by the user which manipulates objects via that action e.g. a ziz-zag motion may erase something on the screen**)**

[ ] Novice [ ] Experienced [ ] Expert

iii) **Do you use WiiRemote controllers with more than one person regularly (i.e. at least once a week)?**

[ ] YES [ ] NO

If **YES** please specify number of people and times per week on average

11) Do you regularly (i.e. at least once a week) use any of the following gesture-based technology[ ] YES [ ] NO **(if no, go to question 12)**

(**if YES please tick all that apply**)

[ ] Multi Touch software [ ] Gesture enabled mouse

[ ] Sony Eye Toy [ ] Apple iPhone

[ ] Other, please specify ___________________________

12) Do you play computer games regularly (i.e. at least once a week) with other people?

[ ] YES [ ] NO

If YES, how often do you play with other people (times per week)?

1-5 [ ]   6-10 [ ]   11-15 [ ]   16+ [ ]

13) How would you rate your skill level at computer games?

[ ] Novice [ ] Experienced [ ] Expert

<u>CONCEPT MAP USAGE</u>:

14) Have you ever used concept mapping software [ ] YES [ ] NO **(if NO, please go to question 15)**

i. **Please indicate your typical use of concept mapping software**

[ ] Daily [ ] Weekly [ ] Monthly

ii. **How would you rate your skill level at concept mapping?**

[ ] Novice [ ] Experienced [ ] Expert

iii. **Have you ever attended an instructional course on concept mapping?**

[ ] YES [ ] NO

iv. **Which of the following best applies to the concept mapping tool?**

for which you have had experience?

Work   [ ] YES [ ] NO

Educational [ ] YES [ ] NO

Other, please specify ___________________________________

If you selected for educational purposes, what course did you use the concept map for and at what level(s) of education i.e. Computer Science, Higher Education?

Please specify ____

v. **Have you used concept mapping software collaboratively?**

[ ] YES [ ] NO (**if NO, go to question 15)**

vi) **Have you used concept mapping software collaboratively with large projected displays?**

[ ] YES [ ] NO

If YES please specify the software and means of interaction with the screen?

(i.e. CMAP Tools, mice and keyboard)**.**

<u>Appendix 5</u>- Pre-session social dominance questionnaire

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
1. I usually take charge of conversations.	1	2	3	4	5	6	7
2. I am often responsible for keeping the conversation going when we talk.	1	2	3	4	5	6	7
3. I usually do more talking than listening.	1	2	3	4	5	6	7
4. I have very little skill in managing conversation.	1	2	3	4	5	6	7
5. I often influence people.	1	2	3	4	5	6	7
6. I am very expressive during conversations.	1	2	3	4	5	6	7
7. I often win any arguments that occur in our conversations.	1	2	3	4	5	6	7
8. I am often concerned with others' impressions of me.	1	2	3	4	5	6	7
9. I have a natural talent for winning over others.	1	2	3	4	5	6	7
10. I feel I have a dramatic way of interacting.	1	2	3	4	5	6	7
11. I am usually relaxed and at ease in conversations.	1	2	3	4	5	6	7
12. I often avoid saying things in conversations because I might regret it later.	1	2	3	4	5	6	7
13. I often have trouble thinking of things to talk about.	1	2	3	4	5	6	7
14. I have a way of interacting that draws others to me.	1	2	3	4	5	6	7
15. I show a lot of poise during interactions.	1	2	3	4	5	6	7
16. I am not very smooth verbally.	1	2	3	4	5	6	7
17. I am usually successful in persuading others to act	1	2	3	4	5	6	7
18. I feel that I have a memorable way of interacting.	1	2	3	4	5	6	7

<u>Appendix 6</u>- Concept map literature

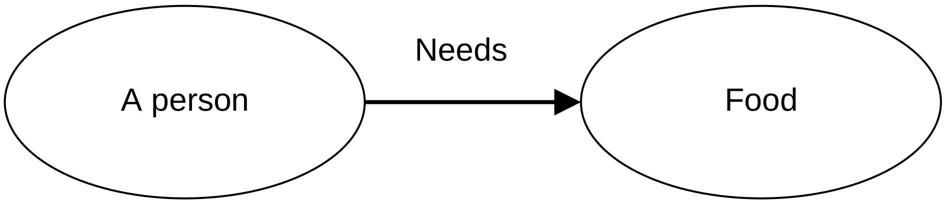
What is a concept map?

- A *concept* represents thoughts or ideas within a domain

- In a *concept map*, the concepts, usually represented by single words enclosed in an oval box, are connected to other concepts by arrows.

- A word or brief phrase, accompanying the arrow, defines the relationship between the connected concepts (see fig: 1). Major concept boxes will have multiple lines linking to multiple other concepts.

Fig 1. A simple concept map indicating a person's relationship to food.



Possible phases of construction

Brainstorming Phase

- From memory, identify terms and ideas that you think are associated with the topic. Your objective here is to generate the largest possible list that you can i.e. redundancy and relative importance is not considered at this point

Organising Phase

- Create groups and sub-groups of related terms. Try to group terms that emphasise hierarchies. Feel free to add items and introduce new terms. You may notice that some concepts will fall into multiple groupings.

Layout Phase

- Arrange a layout which best represents your collective understanding of the interrelationships and connections among groupings.

- Use a consistent hierarchy with the most important concepts in the centre or at the top. With sub-grouping, place closely related items near to each other.

Linking Phase

- Use lines with arrows to connect and show the relationship between connected items. Write a word or short phrase by each arrow to specify the relationship. Many arrows can originate or terminate on particularly important concepts.

Finalising and Review

- Consider if the relationships are correct? Are important concepts missing? Is the concept map laid out so that higher order relationships are easy to follow?

<u>Appendix 7</u>- Post experiment questionnaire

Part 1: Quality of discussion process and outcome

1 The overall quality of the discussion was	poor	1	2	3	4	5	6	7	excellent
2 The discussion, on the whole, was	ineffective	1	2	3	4	5	6	7	effective
3 The outcomes of the discussion were	unsatisfactory	1	2	3	4	5	6	7	satisfactory
4 The content of the discussion was	Chaotic	1	2	3	4	5	6	7	orderly
5 To what extent do you agree with the final solutions to the problem?	Strongly disagree	1	2	3	4	5	6	7	strongly agree

6 What percent do you think your partner influenced the final solution? _____%

7 Did one person emerge as a leader? You:___ Partner: ___ Nobody:___

Part 2: Please evaluate your partner

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
1. This person usually took charge of the conversations.	1	2	3	4	5	6	7
2. S/he was often responsible for keeping the conversation going when we talked.	1	2	3	4	5	6	7
3. S/he usually did more talking than listening.	1	2	3	4	5	6	7
4. S/he had very little skill in managing conversation.	1	2	3	4	5	6	7
5. S/he often influenced me.	1	2	3	4	5	6	7
6. S/he was very expressive during conversations.	1	2	3	4	5	6	7
7. S/he often won any arguments that occurred in our conversations.	1	2	3	4	5	6	7
8. S/he was often concerned with my impressions of him/her.	1	2	3	4	5	6	7
9. S/he had a natural talent for winning over me.	1	2	3	4	5	6	7
10. S/he had a dramatic way of interacting.	1	2	3	4	5	6	7
11. S/he was usually relaxed and at ease in conversations.	1	2	3	4	5	6	7

12. S/he often seemed to avoid saying things in conversations because s/he might regret it later.	1	2	3	4	5	6	7
13. S/he often seemed to have trouble thinking of things to talk about.	1	2	3	4	5	6	7
14. S/he had a way of interacting that drew me to him/her.	1	2	3	4	5	6	7
15. S/he showed a lot of poise during interactions.	1	2	3	4	5	6	7

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
16. S/he was not very smooth verbally.	1	2	3	4	5	6	7
17. S/he was usually successful in persuading me to act.	1	2	3	4	5	6	7
18. S/he had a memorable way of interacting.	1	2	3	4	5	6	7
19. S/he told the truth.	1	2	3	4	5	6	7
20. I believed what s/he told me.	1	2	3	4	5	6	7
21. I could rely on him/her not to make my decisions more difficult by careless thinking.	1	2	3	4	5	6	7
22. Given my experience with him/her, I saw no reason to doubt his/her competence in this task.	1	2	3	4	5	6	7

Part 3: Please evaluate yourself

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
23. I often took charge of the conversation.	1	2	3	4	5	6	7
24. I was often responsible for keeping the conversation going.	1	2	3	4	5	6	7
25. I usually did more talking than listening.	1	2	3	4	5	6	7

26. I had very little skill in managing conversation.	1	2	3	4	5	6	7
27. I often influenced the others.	1	2	3	4	5	6	7
28. I was very expressive during conversations.	1	2	3	4	5	6	7
29. I often won any arguments that occurred in our conversations.	1	2	3	4	5	6	7
30. I was often concerned with my partners' impressions of me.	1	2	3	4	5	6	7
31. I had a natural talent for winning my partners over.	1	2	3	4	5	6	7
32. I felt I had a dramatic way of interacting.	1	2	3	4	5	6	7
33. I was usually relaxed and at ease in conversations.	1	2	3	4	5	6	7
34. I often avoided saying things in conversations because I might regret it later.	1	2	3	4	5	6	7
35. I often had trouble thinking of things to talk about.	1	2	3	4	5	6	7
36. I had a way of interacting that drew the others to me.	1	2	3	4	5	6	7
37. I showed a lot of poise during interactions.	1	2	3	4	5	6	7
38. I was not very smooth verbally.	1	2	3	4	5	6	7
39. I was usually successful in persuading my partners to act.	1	2	3	4	5	6	7
40. I feel that I had a memorable way of interacting.	1	2	3	4	5	6	7

Appendix 8- Post experiment questionnaire

Concept mapping

2) Please rate the level of ease or difficulty in constructing the concept map with the controller for Computer Systems I and II

   a. as a mouse

☐ ☐ ☐ ☐ ☐ ☐ ☐

(easy) 1 2 3 4 5 6 7 (difficult)

3) Please rate the level of ease or difficulty in constructing the concept map with the controller for IP/PDS and Software Applications

   a. With gestures

☐ ☐ ☐ ☐ ☐ ☐ ☐

(easy) 1 2 3 4 5 6 7 (difficult)

Please Comment

4) How attentive/focused did you feel whilst constructing the concept map for

   a. **Computer systems i and ii?**

☐ ☐ ☐ ☐ ☐ ☐ ☐

(focused) 1 2 3 4 5 6 7 (unfocused)

   b. **IP/PDS and Software Applications?**

☐ ☐ ☐ ☐ ☐ ☐ ☐

(focused) 1 2 3 4 5 6 7 (unfocused)

Please Comment

---

5) Please rate your level of preference when using the controller as a mouse for constructing the concept map for

   a. Computer Systems I and II

☐ ☐ ☐ ☐ ☐ ☐ ☐

(liked) 1 2 3 4 5 6 7 (disliked)

Please Comment

---

6) Please rate your level of preference when using the controller as a mouse with gestures for constructing the concept map for

   a. IP/PDS and Software Applications

☐ ☐ ☐ ☐ ☐ ☐ ☐

(liked) 1 2 3 4 5 6 7 (disliked)

Please Comment

Gestures

7) Please rate how easy or difficult it was to create gestures for

a. IP/PDS and Software Applications

☐ ☐ ☐ ☐ ☐ ☐ ☐

(easy) 1 2 3 4 5 6 7 (difficult)

Please Comment

8) Please rate how easy or difficult it was to remember gestures for

a. IP/PDS and Software Applications

☐ ☐ ☐ ☐ ☐ ☐ ☐

(easy) 1 2 3 4 5 6 7 (difficult)

Please Comment

9) Do you feel that personalised gestures would allow you to remember gestures more easily?

☐ ☐

Yes No

If yes, please explain why?

10) Do you feel that the act of gesturing helped you to remember the associative action?

☐ ☐

Yes No

If yes, please explain why?

---

11) Please rate the appropriateness of the gestures assigned to the actions?

	☐	☐	☐	☐	☐	☐	☐	
(appropriate)	1	2	3	4	5	6	7	(not appropriate)

Please Comment

Group Work

12) Did you feel more you contributed more if you were in possession of the controller when the controller was enabled as

a. a mouse?

☐ **Yes** ☐ **No** ☐ **No difference**

b. a mouse with gestures?

☐ **Yes** ☐ **No** ☐ **No difference**

c. I was never in possession of a controller

13) **Please select the statement which bests describes your contribution to the concept map for**

a. **Computer Systems I and II**

i) I created more nodes than links
ii) I created more links than nodes
iii) I created roughly an equal amount of links and nodes
iv) I did not create any links
v) I did not create any nodes
vi) I did not contribute
vii) I contributed in other ways

Please Specify

b. **IP/PDS and Software Applications**

i) I created more nodes than links
ii) I created more links than nodes
iii) I created roughly an equal amount of links and nodes
iv) I did not create any links
v) I did not create any nodes
vi) I did not contribute
vii) I contributed in other way

Please Specify

14) **Please select the statement which bests describes your partners contribution to the concept map for**

a. **Computer Systems I and II**

i) They created more nodes than links
ii) They created more links than nodes
iii) They created roughly an equal amount of links and nodes
iv) They did not create any links
v) They did not create any nodes
vi) They did not contribute
vii) They contributed in other ways
viii) I am unsure what they did

Please Specify

---

ii) IP/PDS and Software Applications

i) They created more nodes than links
ii) They created more links than nodes
iii) They created roughly an equal amount of links and nodes
iv) They did not create any links
v) They did not create any nodes
vi) They did not contribute
vii) They contributed in other ways
viii) I am unsure what they did

Please Specify

Task/environment

15) Was there any factor which disturbed or distracted you during the session?

☐ Yes ☐ No

Please Comment

____

____

16) Do you feel that there was sufficient time to complete the task?

☐ Yes ☐ No

Please Comment

____

____

17) Please rate how easy or difficult you found it to complete the task asked of you for

a. Computer systems I and ii?

	☐	☐	☐	☐	☐	☐	☐	
(Easy)	1	2	3	4	5	6	7	(difficult)

b. IP/PDS and Software Applications?

	☐	☐	☐	☐	☐	☐	☐	
(Easy)	1	2	**3**	**4**	**5**	**6**	**7**	(difficult)

Learning outcomes and knowledge prerequisites

18) **How would you rate your level of confidence in being able to describe how individual modules relate to each other and constitute your degree as a whole?**

☐ **Very confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

Please Comment

---

19) **How would you rate your level of confidence in being able to explain the concept of a learning outcome to another person?**

i) in relation to computer systems?

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

ii) in relation to computer systems II?

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

iii) in relation to Introduction to programming/programming and data structures

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

iv) in relation to software applications

☐ ☐ ☐ ☐ ☐

Very Confident **Fairly Confident** **Not Sure** **Poor Confidence** **Very poor Confidence**

Please Comment

---

20) How would you rate your level of confidence in being able to explain the concept of a knowledge prerequisite to another person?

i) in relation to computer systems?

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

ii) in relation to computer systems II?

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

Iii) in relation to Introduction to programming/programming and data structures

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

iv) in relation to software applications

☐ **Very Confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **very poor Confidence**

Please Comment

---

21) How would you rate your level of confidence in being able to describe how knowledge prerequisites between modules relate to each other?

☐ **Very confident** ☐ **Fairly Confident** ☐ **Not Sure** ☐ **Poor Confidence** ☐ **Very poor Confidence**

Please Comment

22) **What would you do to improve the experience of WiiConcept?**

23) **Any further comments**

Thank you for completing the questionnaire.