UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

Facilitating Group Learner Interactions using Intelligent Agents to Improve Group Knowledge Construction in Collaborative M-Learning: Case of Higher Learning Institutions in Kenya

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A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTORATE OF PHILOSOPHY IN INFORMATION SYSTEMS

2018

Declaration

The work contained in this PhD thesis is my original work and has not been previously submitted at any other educational institution. To the best of my knowledge, this thesis contains no material previously published and written by another person, except where due reference is made.

Date 6/6/2018

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P80/90301/2013

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Dedication

To my dear wife Consolata, daughter Clara and sons Dickson and Casper. You are wonderful gifts from God.

Acknowledgements

First, I am grateful to the Lord God Almighty, who gave me the strength to prevail through this challenging and educative experience. It is within His purpose that I live.

I am greatly indebted to the National Commission for Science and Technology Innovations (NACOSTI) for its financial support through a research grant for this research study. Surely, that contribution made a great impact in this study enabling it to be completed on time.

I also thank my supervisors, Prof. Robert Oboko and Prof. Elijah Omwenga, who gave me all the academic support that I needed. Your guidance and encouragement gave me confidence in this study. Without you, things would have been unthinkable.

I cannot forget the students of Kenyatta University, Dedan Kimathi University of Technology and Murang'a University of Technology. Your contribution and willingness to participate in the research study was outstanding.

I also owe my thanks to my PhD colleagues in the School of Computing and Informatics in the University of Nairobi and the academic fraternity from other universities in Kenya, especially my colleagues in Murang'a University of Technology and Kenyatta University. Special thanks to Mr. John Ndia of Murang'a University of Technology for his assistance during data collection and analysis. Thanks to Dr. Elizaphan Maina Muuro of Kenyatta University for his advice and support. Thanks to Prof. Geoffrey Muchiri for his constant and unending encouragement towards the completion of this study. I cannot forget Mr. Ken Mwirigi Mbaabu and his team for their unrelenting effort to support the development of the mobile learning platform which was used for data collection.

Finally, I salute and give special thanks to my family for their moral, material and temporal support which they accorded me during the entire period of the study. Their understanding when I was not available for them is amazing.

Abstract

This research study aimed to improve the levels of group knowledge construction by providing intelligent-based facilitations to learner group interactions in a collaborative mobile learning environment. The interactions are in form of group participation and cognitive conflicts. Participation in group discussions is of primary importance for active group knowledge construction through interaction with others. However, grouping members together does not give a surety of their participation in those online discussions. Facilitating group participation can motivate members to participate effectively in group discussions leading to enhanced levels of group knowledge construction. Group cognitive conflicts occur when a learner in a collaborative mobile learning environment becomes aware of a discrepancy between his/her existing cognitive framework and new information or experience. The cognitive conflicts stimulate the learning process by making an individual to move from his/her learning sphere and participate with others in the learning process. However, there is a big challenge on how students handle and resolve conflicts during collaborative learning. Intelligent agents were used in this research study to provide support for group interactions by both facilitating group participation and regulating the group cognitive conflicts.

This research study uses an experimental design with four experimental studies. Experimental study 1 investigated the effect of facilitated group participation on the level of group knowledge construction. The participants were grouped into discussions groups of three members each, and then randomly assigned to three treatment groups. Experimental study 2 investigated the effect of regulated group cognitive conflicts of the level of group knowledge construction. It also used an experimental design with one control group and two experimental groups. The participants were grouped into discussion groups and then randomly assigned to the three treatment groups in a repeated measures study. Experimental study 3 investigated the moderating effect on the task complexity on the relationship between the facilitated group participation and the level of group knowledge construction while experimental study 4 investigated the moderating effect of task complexity on the relationship between the regulated group cognitive conflicts and the level of group knowledge construction.

The results from experimental study 1 showed a difference in knowledge construction among the participants in different groups as a result of using different facilitations for group participation. Experimental study 2 results showed a difference in knowledge construction among learners using the regulated group cognitive conflict features and those not using it. Experimental study 3 results showed that the presence of group participation was not the only determinant on the level of group knowledge construction. Task complexity significantly predicted level of group knowledge construction. The results of experimental study 4 showed that both regulated group cognitive conflicts and task complexity significantly predicted level of knowledge construction.

From both experimental study 1 and 2, it was concluded that the use of both facilitated group participation and regulated group cognitive conflicts improved the level of group knowledge construction. The conclusion from experimental study 3 is that task complexity has a moderating effect on the relationship between the facilitated group participation and the level of group knowledge construction. Experimental study 4 concluded that task complexity has a moderating effect on the relationship between the regulated group negotiation and the level of group knowledge construction. The research recommends the use of intelligent agents for effective collection and analysis of group interactions to encourage participation and dynamically regulate the group discussions.

Keywords*:* Collaborative m-Learning, Group Interactions, Group Learner Participation, Group Cognitive Conflicts, Group Knowledge Construction, Intelligent Agent, Moodle.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AI – Artificial Intelligence

ANOVA – Analysis of Variance

CA - Conversational Agent

CL – Collaborative Learning

CmL – Collaborative Mobile Learning

CPS – Collaborative Problem Solving

CSCL – Computer Supported Collaborative Learning

DAI - Distributed Artificial Intelligence

DSS – Decision Support Systems

ERD – Entity Relationship Diagram

HLIs – Higher Learning Institutions

IAM - Interaction Analysis Model

ICLS - Intelligent Collaborative Learning System

IPA - Intelligent Pedagogical Agent

ITS - Intelligent Tutoring System

ITU - International Telecommunication Union

LMS - Learning Management System

M-Learning – Mobile Learning

MADLC - Mobile Application Development Lifecycle

MAS - Multi-Agent System

MCL – Mobile Collaborative Learning

mCSCL - Mobile Computer Supported Collaborative Learning

Moodle - Modular Object-Oriented Dynamic Learning Environment

NACOSTI – National Commission for Science and Technology Innovations

SDK – Software Development Kit

SPSS – Statistical Package for Social Scientists

TEL - Technology Enhanced Learning

UNESCO – United Nations Educational, Scientific and Cultural Organization

Glossary

Mobile Device: This is a hand-held device that is portable anywhere (e.g. carried in a pocket), is accessed anytime with no breakage in its transmission signals (Mwendia et al., 2014) and is always with the student, and always on (Kolb, 2011).

Mobile learning (M-Learning): Use of mobile devices for learning and learning support (Muyinda et al., 2010).

Group Problem: This is a type of problem which brings together stakeholders who through their analytical decision making abilities can influence the outcome of the problem (Raison et al., 2015).

Group Knowledge: This is an outcome of collaborative learning when group members engage in solving a group problem (Shukor et al., 2014).

Group Knowledge Construction: A set of high-level interactive processes where information is shared by pooling together different pieces of information from multiple sources such as group members (Näykki, 2014).

Group Participation: This is a situation where participants express themselves and make significant contributions to a group problem (Rimor et al., 2010).

Group Cognitive Conflicts: This is a contradictory phenomenon which occurs between cognitive student’s knowledge structure and new information from group members (Jiangnan et al., 2014)

Ill-structured Problems: These are complex problems which are not clearly and fully defined, and have inadequate information provided in the problem statement. The goals for solving them are not well defined, they consist of multiple ways of solving them, and without optimal solution among the many possible solutions, and with a possibility of no solution at all (Oboko, 2012).

Well-structured Problems: These are simple problems which are clearly defined in terms of their initial and goal states, and the set of local operators for transition from initial to goal states (Oboko, 2012).

Intelligent Agents: This refers to software that assists a person, or acts on behalf of that person, in performing repetitive computer-related tasks, such as finding and collecting information from a source and presenting it to the person requiring it (Haag et al., 2018).

Chapter 1: Introduction

1.1 Introduction

The traditional method of delivering learning content through lecturing only is getting replaced with mixed delivery methods such as group discussions and peer reviews (Rocca, 2010). Group discussions, although popular in most learning management systems, face some challenges during group interactions. This research study aimed to provide collaborative mobile learning support through facilitated group interactions. The research study concentrated on two types of group interactions: group participation and group cognitive conflicts. The collaborative learning facilitations were provided within a collaborative mobile learning environment in higher learning institutions (HLIs).

1.2 Research Background

The 21st century skills required for education consist of what is referred to as the 4 C's namely collaboration, critical thinking, communication, and creativity (NEA, 2010). Collaboration is a core competency in modern knowledge economy and plays a central role in education research (von Davier & Halpin, 2013). Collaborative learning involves two or more people interacting with each other under certain circumstances leading to improved learning (Dolmans et al. 2005). Collaborative learning has been proved to be effective on group learning, especially for low-achieving students (Lai, 2011), who gain a lot from the interactions which arise during learning. Students enjoy and get benefits from collaboration by interacting with each other, where they see each other as additional educational resources (McLaren, 2014).

This research study is based on two learning theories: Social Constructivist Theory and Social Cognitive Theory. It also borrows from the Social Interaction Theorem. According to Social Constructivist Theory, knowledge is created when learners interact and collaborate with each other (Vygotsky, 1978) through a social process of knowledge building (Said et. al, 2015). In Social Cognitive Theory, cognition is a group process, where knowledge construction occurs when group members engage in learning activities, receive feedback and participate in group interactions (Bandura, 2001). Social Interaction Theorem identifies three different types of interaction possible in collaborative learning (student-student, student-instructor, student-content).

The growth of mobile phones in the world in both developed and developing countries has been unprecedented in the 2000s. A penetration rate of 87% has been achieved through an estimated 5.9 billion subscriptions for mobile phones worldwide, with 79% attained in the developing world which is almost as high as the global average (ITU, 2011; UNESCO, 2012). Mobile devices such as mobile phones and various players (mp3, mp4, mp5) have become so common with people and more preferred than desktop computers, due to their unique features such as portability, adaptability, flexibility, intuitiveness, and comparatively cheap prices (El-Hussein & Cronje, 2010).

The use of mobile phones as connected computing devices with a multitude of services has made their use to be beyond mere conversational devices (Ford & Leinonen, 2010). Other than using them for making ordinary calls, mobile phones provide socializing features, which provide a form of interaction, either in the formal or informal setup. The use of mobile phones for both personalized and collaborative learning has become a common occurrence in education sector. Students use mobile phones to engage in class work which involve collaboration through social media. In his research, Jacobs (2010) noted that most students (61%) reportedly get excited and engaged when discussing class topics and debates using mobile phones. With such learning initiatives, learners are shifting the learning from the schools and campuses to outside the classroom setting. This shift to informal activities is said to motivate learners since they have freedom to define their own learning tasks and can relate their learning activities to their own goal which they have control over (Jones et. al. 2006).

Computer Intelligence can provide support for learner collaboration (Downes, 2012), as an essential and necessary aspect of effective learning. Computer agents have been used to provide control over interaction in group learning (Looi, 2014).

1.3 Research Problem

The success or failure of collaboration during collaborative learning has been measured by most researchers using quantitative results as a learning outcome (Cerny & Mannova, 2011). Stahl (2011a) agrees that most research on collaborative learning emphasizes on quantitative relationships among variables - such as the impact of group size on group learner participation – rather than measuring the groups' knowledge building processes. Thus, most of previous research work put little emphasis on social interactions between members (Yee-King et. al, 2014) within a collaborative group. According to Järvelä (2014), there is not enough research about how group members engage, sustain and productively regulate collaborative processes. For example, according to Aarnio (2015) not much research has been done on how students handle and resolve conflicts on knowledge which arise during collaboration and how such conflicts can be facilitated. This problem also exists in collaborative mobile learning systems.

M-learning is still immature in areas of pedagogical considerations (Park, 2011). Most mobile learning systems do not provide support for the collaborative learning processes (Wu et al., 2012), with only a few mobile learning systems having explicitly addressed the problem of mobile devices in the foreground of interaction (Eliasson, 2012). In their meta-analysis involving 164 published papers from 2003 to 2010, Wu et al. (2012) noted that the most researched topic in mobile learning was assessing the outcomes (product) of mobile learning rather than collaborative processes. Thus, a lot of research in m-learning has been driven by the capabilities of the mobile devices and the technical challenges, but little has been done on how meaningful and productive mobile technology supports collaboration (Park, 2011).

Interaction, as a form of group processes, among learners in collaborative learning is the key element in group learning (Näykki, 2014). However, it is a challenging task to facilitate an effective learning experience through quality student interactions (Song & McNary, 2011). Intelligent Agents have been used in collaborative learning to provide pedagogical guidance, tutorials, to find learning resources, track learners' progress and, assist in collaborating and communicating learning functions (Soliman & Guetl, 2010a). However, there lacks sound framework and methodological approach of using agents in collaborative learning (Adla et al., 2012).

This research study concentrates on group interactions which occur during collaborative learning with emphasis on group participation and group cognitive conflicts. The study aims to provide facilitations for those interactions in order to improve levels of group knowledge construction. The facilitations will be implemented using intelligent agents.

1.4 Research Objectives

Main Objective

The main objective of this research study is to investigate effectiveness of strategies and ways of improving levels of group knowledge construction in collaborative mobile learning when learners are provided with agent-based facilitations for group participation and regulation of group cognitive conflicts.

Specific Objectives

The specific objectives are:

1. To design, develop and implement a collaborative m-learning prototype using intelligent agents to facilitate group interactions.
2. To investigate the effect of facilitated group participation on the level of group knowledge construction in collaborative m-Learning group interaction processes.
3. To investigate the effect of regulated group cognitive conflicts on the level of group knowledge construction in collaborative m-Learning group interaction processes.
4. To investigate the moderating effect of task complexity on the relationship between facilitated group participation and level of group knowledge construction in collaborative m-Learning group interaction processes.
5. To investigate the moderating effect of task complexity on the relationship between regulated group cognitive conflicts and level of group knowledge construction in collaborative m-learning group interaction processes.

1.5 Research Questions

All the research questions used in this research study are based on the objectives of the research study.

Research Question 1

This research question is based on objective 1.

> *Can a mobile application be designed, developed and implemented for facilitating group interactions using intelligent agents?*

Research Question 2

This research question is based on objective 2.

> *Which groups of learners (those using facilitated group participation or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?*

Sub-Question 2a

Which groups of learners (those using informative feedback facilitation or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?

Sub-Question 2b

Which groups of learners (those using turn taking or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?

Research Question 3

This question is based on objective 3

> *Which groups of learners (those using regulated group cognitive conflicts or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?*

Sub-Question 3a

Which groups of learners (those using role playing or those not using) achieve higher levels of knowledge construction in collaborative m-learning group interaction processes?

Sub-Question 3b

Which groups of learners (those using guided negotiations or those not using) achieve higher levels of knowledge construction in collaborative m-learning group interaction processes?

Research Question 4

The research question is based on objective 4

> *Does task complexity affect the relationship between facilitated group participation and level of group knowledge construction?*

Research Question 5

This question is based on objective 5

> *Does task complexity affect the relationship between regulated group cognitive conflicts and level of group knowledge construction?*

1.6 Structure of the Thesis

Chapter 1 gives a general introduction to the study. Chapter 2 is the Literature Review which forms the theoretical background on which the research study is based upon. Chapter 3 discusses the methodology for design, development, implementation and validation of the Agent-based prototype for collaborative mobile learning. Chapter 4 discusses the Research Methodology (Experimental Design) for this study. Chapter 5 presents the Results and Discussions, and Chapter 6 gives the conclusions, contributions and further work of this research.

Chapter 2: Literature Review

2.0 Introduction

Learners require skills to enable them to learn with ease; among such skills include collaboration (Hämäläinen & Vähäsantanen, 2011). Even though learning, to an extent, depends on the individual's cognitive ability, it is more effective when it becomes a group's joint effort and when treated as a social activity (Domalewska, 2014).

Mobile devices allow students to communicate what they have learnt, critically analyze information and create new knowledge through their interaction (Dabbagh & Kitsantas, 2011). However, only a few research areas in m-learning have explicitly addressed the problem of mobile devices in the foreground of interaction (Eliasson, 2012).

Computer technology has been used to facilitate teacher's planning, intervention and tracing the learning process with respect to the usage of resources (Isik & Saygili, 2015). Computer Intelligence can support learner collaboration (Downes, 2012) as an essential and necessary aspect of effective collaborative learning.

The rest of the chapter is divided into the following sections. Section 2.1 discusses the Learning Process, section 2.2 Collaborative Mobile Learning, section 2.3 Collaborative Interactions in Group Learning, section 2.4 Collaborative Knowledge Construction, section 2.5 Facilitating Collaborative Interactions, section 2.6 Computer Intelligence and Collaborative Learning, and section 2.7 Summary of the Literature Review.

2.1 Learning Process

2.1.0 Introduction to Learning Process

Learning is a process which involves an active construction rather than communication of knowledge (Lainema, 2009). Learning becomes more effective when it becomes a group's joint effort and when treated as a social activity (Domalewska, 2014). The process of learning allows students to grow their interest and promote the sharing of ideas with each other while becoming responsible for their own learning (Karatas & Baki, 2013). The learners intentionally engage in the learning process when creating meaning from their information and experience (Crow & Nelson, 2015). According to Gunter et al. (2002), the most important thing that really matters to learners is the meaning they construct for themselves. Effective learning occurs when members in a group solve a group problem together through sharing of ideas.

2.1.1 Problem Solving Processes

Problem solving, as an instructional method, allows students to understand and take ownership of the learning process (Karatas & Baki, 2013). Group problem solving arises from the joint effort to solve problems together as a group. Group problem solving enables effective learning to be achieved through active group construction of knowledge informed by multiple ideas from different members. This makes group problem solving an important component in group learning.

There are many approaches to problem solving. This section discusses two of these approaches: one by Sternberg (2009) and the other one by Voss and Post (1988).

According to Sternberg (2009), problem solving cycle consist the following steps: problem identification, problem definition/representation, strategy formulation, organization of information, allocation of resources, monitoring, and evaluation. In problem identification, the learners recognize the goal of problem solving. The problem is clearly articulated in measurable terms using a constructed mental model of the entire problem and its sub-problems, identifying its boundaries. In strategy formulation, the steps required to solve the problem are generated and incorporated within a workable strategy. This also requires a justification for the selected solution. Organizing information deals with the decisions on how to represent the information about the problem, to make it easy to the problem solver when implementing the problem solving strategy. The allocation of mental and physical resources such as time, money, equipment and space is done in the resource allocation step. Monitoring involves checking on one’s resource usage e.g. time, as well as progress towards the goal in the course of problem solving, instead of waiting until the end. This also allows for remedial action to be taken if necessary. Evaluation involves making judgment on the solution after the problem has been fully solved, and may lead to new problems being recognized, the problem being redefined or new strategies coming to light (Sternberg, 2009).

According to Voss and Post (1988), problem solving comprises of problem representation, solution process, monitoring and evaluation, with justification for all the decisions/choices made. The construction of the problem space, definition of sub-problems, searching and selecting information for solving the problem are done during problem representation. Solution generation involves generating alternative strategies for solving the problem, including the steps to be followed, the knowledge and skills to be applied and the resources to be expended for each alternative solution. The solution process involves both solution generation and solution selection. Solution selection involves identifying the best solution from among the alternatives and providing the reasons for it. Monitoring checks the usage of resources and the progress made towards solving the problem. It is necessary to take steps to ensure that problem solving remains on course. During evaluation, it is established whether the problem has been solved well and if not, to identify any other improvements which can be made to solve the problem better, such as consideration of alternative solutions. Figure 2-1 shows a typical problem solving model.

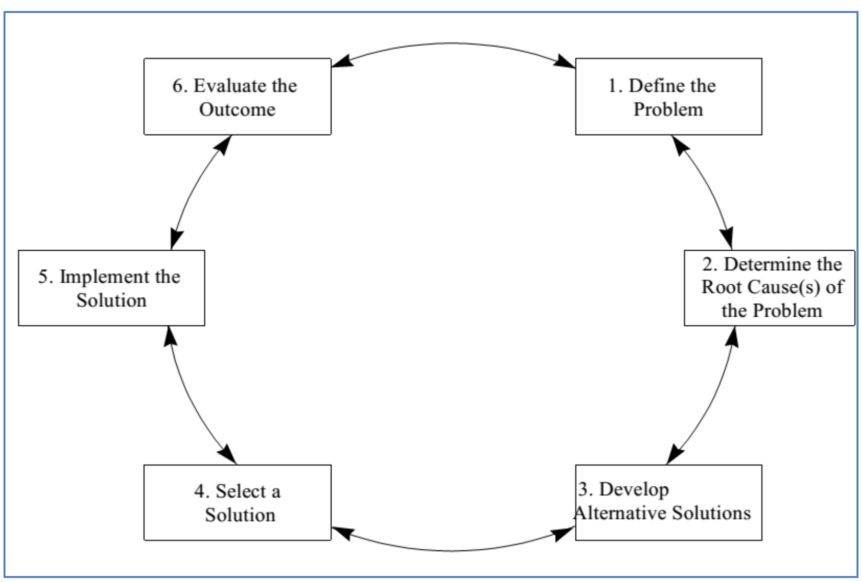


Figure 2-1: Problem Solving Model

2.1.2 Collaborative Problem Solving (CPS)

Researchers agree that one of the ways of improving the learning process is through collaboration (Cerny & Mannova, 2011). In collaborative problem solving (CPS), the group members engage in the process of sharing the understanding in order to get an effective solution by pooling their knowledge to reach that solution. Collaborative problem solving requires coordination of the group processes through communication amongst the group members. In CPS, the individual problem solving processes and communication processes interact with the cognitive processes of the team members (OECD, 2013). Even though the cognitive processes in CPS are internal, they are also exhibited during interactions with the group task and with group members. The cognitive burden is seen to be shared when the members collaborate, by distributing the cognitive sub-tasks across the individuals, for example, by members justifying their actions. This makes explicit the strategic knowledge that would otherwise remain implicit (Jaimini, 2014).

In summary, group problem solving involves four basic constructs: (a) group task, (b) group structure, (c) group process, and (d) group product (Laughlin, 2011). Group task is what the group does. Group structure deals with how the group is organized through different roles, different beliefs and behaviors of the group members, and different member characteristics such as their demographic, physical, and psychological attributes. Group process describes group members' interactions and how they influence one another. Group product is the collective group outcome.

In successful groups, members engage each other's thinking through interaction during group problem solving (Barron, 2003). However, the main challenge is the implementation of collaboration in the learning process, that is, effective implementation of collaborative learning (Wicaksono, 2013). According to Aarnio (2015), the tutor has a role to facilitate the learning process rather than to provide information during learning. The next section discusses collaborative learning and its challenges with respect to mobile devices and in the context of group problem solving processes (collaboration).

2.2 Collaborative Mobile Learning

2.2.0 Introduction

Collaborative learning allows two or more learners to learn together (Dillenbourg, 1999). Collaborative learning is based on social constructivism, where knowledge is created when learners interact and collaborate with each other (Vygotsky, 1978). In collaborative learning, the learners participate in a common task, and each individual depends on, and is accountable to each other (Filigree Consulting, 2012). Kirschner et al. (2008) defined collaborative learning as a form of learning and interaction which involves knowledge co-construction and mutual engagement or participation as well as group coordination. Generally, collaborative learning allow students to become more engaged in deeper learning, retain information better and for a longer time (Reed, 2014; McLaren, 2014), and get better learning outcomes than those of individual learners (McLaren, 2014).

According to McLaren (2014) a collaborative learning group can range from a pair of students (called a dyad), to a small group (3-5 students), to a classroom learning (25-35 students), on to a large-scale online learning (hundreds or even thousands of students).

Collaboration has benefits such as (i) integration of knowledge from multiple sources of knowledge, experiences, and perspectives, and (ii) enhanced quality of solutions inspired by ideas from various group members (OECD 2010). Collaboration jointly produces something new from the group interactions, which are facilitated by bonds established and maintained by the group members themselves (ARACY, 2014).

Just like any other form of learning, collaborative learning requires an infrastructure for delivery of learning material to the learners. Mobile devices such as mobile phones, laptops, tablets and others have been used as mobile learning platforms. Nowadays, mobile devices are preferred over desktop computers (El-Hussein & Cronje, 2010) and their use for educational purposes is becoming a common expectation of learners (Lan & Huang, 2012). The use of mobile phones for collaboration is in line with the tenets of constructivism which involves both teachers and students as active participants in the learning processes (Dabbagh & Kitsantas, 2011).

In as much as collaborative learning may stimulate their participation, students can do very little in the short time duration of an ordinary class lecture. Students can take advantage of the mobile devices to facilitate flexible collaboration in and out of classroom settings (Cheong et al., 2012). According to Wong and Looi (2011), mobile technology can play a role of enhancing learning whenever and wherever students are motivated to learn. Researchers agree that the future of teaching and learning in collaborative environments will be greatly influenced by m-learning (El-Hussein & Cronje, 2010).

2.2.1 Collaborative M-Learning

According to Hamdan and Schaper (2012), mobile devices become interactive when they are used in collaborative environments. Mobile learning, though often synonymous with mobile phones, actually covers a broader range or aspects, more than just mobile phones. Henry & Sankaranarayanan (2010) define mobile learning as e-learning that uses mobile devices to allow for movement from place to place facilitated by connectivity through a variety of wireless technologies. According to Wexler et al. (2008) m-learning is any activity that students engage in using mobile devices which makes them more productive in consuming, interacting or creating information.

According to West (2013) mobile devices provide some of the easiest ways for students to collaborate. Collaborative mobile learning involves the use of mobile devices to allow two or more people to learn something together. Various terms are used in the literature review to refer to the use of mobile devices for collaborative learning. Among them include Collaborative Mobile Learning (CmL), Mobile Collaborative Learning (MCL) and Mobile Computer Supported Collaborative Learning (mCSCL). Cml is defined as the use of handheld devices in the classroom to connect with provided location-based content to achieve learning (Chiu & Huang, 2015). Mobile collaborative learning (MCL) is a small group learning application, in which students can obtain knowledge about a topic and concept via communicating with other students by mobile devices (Lee, 2011). mcSCL which is an extension of Computer-Supported Collaborative Learning (CSCL) is used as the link between m-learning and e-learning.

Collaborative mobile learning assists students to clarify learning concepts from their fellow students (The Metiri Group, 2009).
There are a number of benefits learners get from mobile learning. UNICON (2011) gives the following as the benefits of mobile learning: ‘Just enough’ learning - highly applied, easily digestible learning for increasingly busy executives; ‘Just-in-time’ learning – convenient and flexible learning at the exact moment learning is required; ‘Just-for-me’ learning - learner-driven learning in a suitable format, and; Technology - mobile learning can be cost effective and using a learner’s own mobile device eliminates technological barriers to accessing learning.

Mobile devices are not just communication devices, but provide technology which students can collaborate with (Cheong et al., 2012). According to Kim et al. (2014) the rich communication channels provided by collaborative learning using mobile devices improve both the quality and quantity of interactions. The use of mobile phones for learning facilitates interactive group discussions thus enhancing individual and group learning outcomes (Duncan et al., 2012) and allows for new learning experiences, by supporting peer collaboration (Wijers et al., 2010).

Laru (2012) argues that mobile devices are not just cognitive tools that reorganize how learners think; rather they are important for engaging learners in productive learning. Collaborative m-Learning allows student ownership and control of learning processes enabling them to explore new things since they are less reliant on teacher's feedback (Martin et al., 2010). Winters (2006) identifies some key characteristics on meaningful m-learning such as enabling knowledge building by learner and enabling learners to construct understanding using mobile technology. With these features in consideration, a complete definition of collaborative m-learning would incorporate among others, the knowledge building by learners and construction of understanding. The feature of knowledge construction through interactions is a core thing in group learning.

2.2.2 Challenges in Collaborative M-learning

The high availability of mobile phones to the learners does not translate into their use for m-learning. Most mobile phone users engage themselves in making calls and other social activities like the use of social media. It's only a few users who see learning using mobile devices a core pedagogical activity (El-Hussein & Cronje, 2010).

Technology affordances play an important role of providing the facility for group interaction, but it does not define mobile learning interaction. Technology supports interaction by offering the needed qualities to fulfill the requirements for the interaction (Botha et al., 2010). Nouri (2011) points out that even though research about opportunities of mobile technology is rich, collaboration in mobile learning has been rarely considered. Only a few projects have explicitly addressed the problem of mobile devices in the foreground of interaction (Eliasson, 2012). Again, most researchers have measured the effectiveness of m-learning outcomes (product) rather than learning processes (Hwang & Tsai, 2011).

There are some common challenges present in online collaborative learning. For example, Clegg et. al (2013) identified some non-productive contributions during group discussions, such as (i) learners focusing on ideas or topics unrelated to the learning context disrupting the conversation, (ii) learners interrupting each other when not during their turns, (iii) learners derailing the conversation through disruptive behavior, and (iv) learners engaging in the unnecessary social disagreements leading to distractions.

2.2.3 Collaborative M-Learning Theories

The approach to interactions during collaboration can be elaborated using two collaborative learning theories and one collaborative interaction theorem. They include the social constructivist theory, the socio-cognitive theory and the social interaction theorem.

According to social constructivist theory, knowledge is developed when learners engage in active construction of knowledge through social interaction (Vygotsky, 1978), rather than through transmission of knowledge (Schellens & Valcke, 2006). Collaborative learning provides students with learning opportunities through dialogue and argument (Pritchard & Woollard, 2010) to allow them to construct sharable artifacts (Girvan et al., 2013). Thus, collaborative learning is regarded as a social process of knowledge building (Said et al., 2015) where learners are assisted by More Knowledgeable Others (Vygotsky, 1978). This process enables the learners to move from the intrapersonal world of “personal understanding” to building artifacts based on collaborative knowledge building (Stahl, 2011b). Since learners build knowledge through negotiation of meaning (Porcaro, 2011), they become knowledge-generators rather than knowledge consumers. The aim of constructivist approach is to facilitate the students’ construction of their knowledge coupled with more freedom to reflect on the problems together (Mthembu & Mtshali, 2013).

In the social cognitive perspective, knowledge construction takes place when group members engage in learning activities, receive feedback and participate in group interactions (Bandura, 2001). According to socio-cognitive perspective, individual knowledge is an important outcome of collaborative learning, and productive interaction a way to foster individual learning (Deiglmayr & Rummel, 2015). In this respect, cognition is a viewed as a group process with learning and knowledge being shaped by the interactions (Bandura, 2001). Within the socio-cognitive context, cognitive conflicts which occur during collaboration are critical in triggering knowledge creation. It is through social interactions where such conflicts are facilitated leading to advanced levels of learning (Lai, 2011). Thus, learners’ involvement in knowledge construction, in its most successful form, leads to profound learning and understanding (Dochy et al., 2003). The social cognitive theory advocates for an active learning environment where students get highly engaged through social interactions with peers, instructors, and content. Through active learning, students get involved in doing things together through discussions, debates, role playing, and problem based learning (Schunk, 2012). Research has shown that higher interactivity in collaborative environments leads to better learning outcomes and contentment over less interactive ones (Mahle, 2011). Thus, the socio-cognitivists view collaborative learning in terms of students’ involvement in the process of knowledge construction, which leads to deep learning and understanding through sharing (Strijbos, 2011).

The interaction equivalency theorem by Anderson (2003) examines three different types of interaction present in collaborative learning (student-content, student-instructor, and student-student). Student-content interaction allows student to engage to the subject matter presented to him/her, and which results in changing the student’s understanding, perspective or cognitive structures of the student's mind (Moore, 1989). Student-instructor interaction defines the communication between instructor and student in form of counsel, support and encouragement provided by the instructor to the student (Moore & Kearsley, 2012). With this, the instructor inspires and motivates the students into learning. Student-student interaction allows students to share ideas with or without the presence of an instructor. Bouhnik and Marcus (2006) define a fourth type of interaction, student-system interaction, as accessibility of the modern technology for the learners and the instructors using an e-learning system. Some examples include use of discussion forums and emails.

Researchers have associated successful collaborative learning with two cornerstones, which are based on constructivism: (a) productive collaborative interactions, and (b) shared knowledge construction (Järvelä & Hadwin, 2013). This is in line with the two theories above which emphasize the concept of group knowledge creation, and the interaction theorem which indicates the importance of providing support for facilitating interactions to improve the process of knowledge creation.

2.3 Collaborative Interactions and Group Learning

2.3.0 Introduction

According to Näykki (2014), interaction among learners in collaborative learning is the key element in group learning. As a social interaction, collaborative learning involves a number of group members who acquire and share their learning experience or knowledge (Zhu, 2012). Students learn more effectively by externalizing and articulating their unformed, still-developing understanding together (Chi, 2009). Based on the definition of collaborative learning by Patel et al. (2012) collaborative learning is an interaction which involves two or more people who work together to achieve a common goal. Going by this definition, collaborative learning is not merely attained by having learners in a group or providing them with collaborative computer-based tools (McLaren et al., 2010). Group interaction amongst the group members is a necessity.

Learning cannot take place in collaborative environment in the absence of social interactions. Group members must question, analyze, synthesize, evaluate, and make decisions together

(Deloach & Greenlaw, 2005). The social nature of human beings enable them to get information and knowledge by interacting in groups, with learners being actively involved in learning activities (Adnan & Hassan, 2014). Individual processes and structures are traceable to interaction with others where an individual comes into contact with meaning through joint activities (Damşa, 2013).

Student engagement in the learning process is vital in promoting collaborative learning (Liu et al., 2015). Learners engage in higher mental processes when creating knowledge through social negotiations and interactions (Laru, 2012). It is during this engagement when students ask and respond to questions, reflect on contributions from their peers, show initiatives and become responsible for their own and other's learning (Khoshneshin, 2011).

Learners get opportunities for knowledge co-construction through sharing, questioning and justifying one's own ideas and understanding, and those of others (Chi, 2009; Dillenbourg 1999). According to Razzaq et al. (2009), social interactions which support collaborative learning include asking questions, explaining and justifying opinions, articulating reasoning, and elaborating and reflecting on knowledge. Other interactions include clarifying or giving support (Mansor & Rahim, 2009). Students reach high-level knowledge construction when they get involved in arguments, justification, or decision making transforming them into critical thinkers (McLoughlin & Luca, 2000). During collaboration, students provide explanations of their knowledge understandings through elaborations and knowledge re-organization (Van Boxtel, et al., 2000). Hamdan and Schaper (2012) pinpoint interactions within collaborative environments in terms of negotiations, interactive problem solving, and synchronous communication. High level cognitive activities such as analytical thinking, integration of ideas and reasoning are realized during interactions (Rosé et al., 2008). Such high levels can only be attained through elaborations, explanations, questions, argumentations and conflicts during collaborative learning.

Since the quality of interaction determines the level of achievement on collaborative learning where knowledge is co-constructed through interactions among collaborators (Lai, 2011), there is need to study the group interactions among participants in order to understand how groups construct knowledge (Stahl, 2011a). Blake and Scanlon (2012) emphasize on the need to study the group interactions which occur among group learners to recognize what happens at the group level during collaborative learning.

Effective group interaction is determined by some issues, which if not considered can negatively affect group learning outcomes. Discussed in the next three sub-sections are some factors which affect the levels of group knowledge construction, namely task complexity, learner participation and cognitive conflicts.

2.3.1 Group Task Complexity

The problems solved by groups can be either categorized as well-structured or ill-structured. Well-structured problems have single solutions, optimal solution paths, and structured goals. Solving well-structured problems normally involves representing the problems, searching for solutions, and implementing solutions (Chen & Li, 2015). Since they have single, fact-based answers, when one student responds correctly there is really no need for further discussion (Dennen, 2005).

Ill-structured problems have unclear goals that allow for multiple solution paths and multiple solutions (Chen & Li, 2015). They are complex, poorly defined and usually require learners to negotiate issues and meanings (Jonassen, 1997). Their problem constraints are not in the problem statement, their solutions are neither right nor wrong, and not valid or invalid (Chin & Chia, 2005) and they can change from circumstance to circumstance (Voss and Post, 1988). Since solutions to these problems are neither right or wrong nor valid or invalid, they are regarded in terms of level plausibility or acceptability (Chin & Chia, 2005).

The solution process of an ill-structured problem is different from that of a well-structured problem (Chin & Chia, 2005). The primary requirements for ill-structured problems solving are problems representation, justification skills, monitoring, and evaluation (Chen & Li, 2015). Since ill-structured problems consist of a multiplicity of possible solutions (Chen & Li, 2015), justification becomes necessary because of the complexity of such problems (Zhang, 2004). Convincing and well-argued explanations to support selections as well as evidence from facts to back these explanations must be provided during problem solving. Learners solving such ill-structured problems that have no absolute solution must explain their viewpoints to their group members, and justify their opinions (Soller, 2001). Hew and Cheung (2011) postulates the need to incorporate ill-structured problem solving tasks in online discussion because well-defined ones do not raise the need for discussion at all.

Providing learners with an ill-structured problem not just give them the problem to be solved, but something to guide the entire learning process. The problem provides learners with conflict or puzzlement which they seek to address through the process of problem solving (Oboko, 2012). That way, they collaboratively construct explanations and solutions to the problem. Such construction requires both activation of their prior knowledge and stimulating the collaborative processes (Aarnio, 2015).

Stanton & Ophoff (2013) asserts that task complexity determines the level of participation by group members when solving a group problem. Meaningful learning takes place effectively when group members engage in a controversial issue (Ractham & Kaewkitipong, 2012). The nature of the shared task plays an important role in determining the level of interaction. Tasks which are trivial, obvious and unambiguous do not provide opportunities for group negotiation because there is little or nothing to disagree about (Dillenbourg, 1999). Thus, the complexity of the group task (or lack of it) may make the group members to compete with each other within the group or individuals to work individually by ignoring their group members (McCully et al., 2013).

In line with Blooms' taxonomy (1956), well-structured problems can be categorized as knowledge and comprehension problems, semi-structured problems (intermediate problems between well-structured and ill-structured) as application and analysis problems, and ill-structured problems as synthesis and evaluation problems. In Figure 2-2, selecting the learning objectives based on Bloom's taxonomy (1956) greatly determines the level of engagement by the collaborative m-learners based on their learning activities.

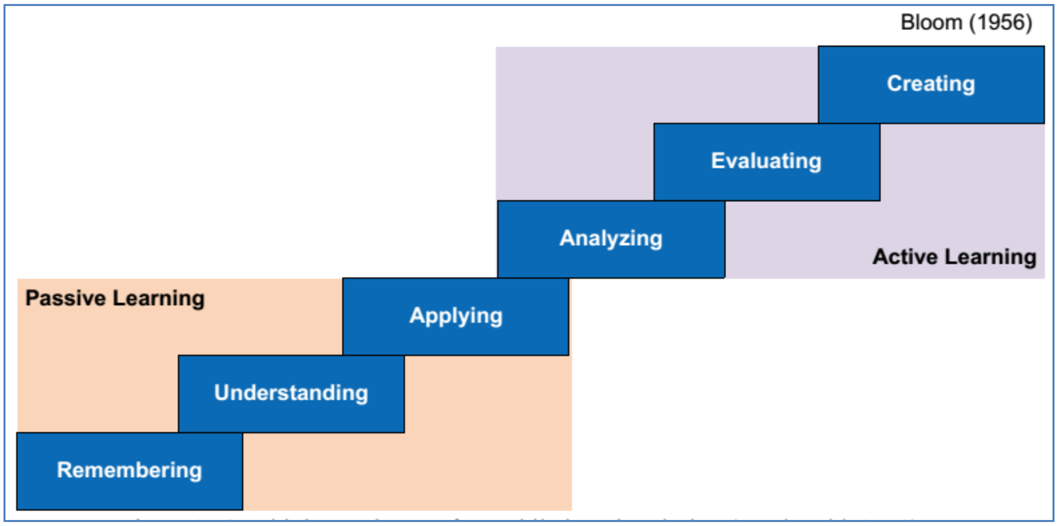


Figure 2-2: Combining pedagogy for mobile learning design

(Source: Krathwohl, 2002)

In summary, well-structured problems lead to passive collaborative learning compared to ill-structured problems which makes collaborative learning to be more active.

2.3.2 Group Learner Participation

Collaborative learning is a social activity which requires learner participation (Wendt, 2013). Rocca (2010) defines participation as making comments, asking questions and even showing an intention to contribute. In a collaborative learning environment, members participate in a conversation, question each other, give and defend their ideas and experience, and get actively engaged (Srinivas, 2011). When students engage in collaborative learning, conceptual changes take place (Biggs & Tang, 2011) which shape, elaborate and deepen their understanding. Learners' participation drives collaborative learning through integration of ideas and concepts, and promotion of problem solving, critical and active thinking skills (Hrastinski, 2009).

According to Coonan (2012), participation in collaborative learning is one of the main drivers for learning success. Engaging in a dialogue, especially an argument is vital to collaborative learning from a constructivism view (Pritchard & Woollard, 2010). Learner participation enhances collaborative learning (Parveen & Batool, 2012) by fostering higher order thinking skills to allow students to engage in group problem-solving (Herrmann, 2013). Engagement allows for structuring and restructuring of ideas within a discussion group, with multiple views coming from individuals used in negotiation of meaning (Bhattacharjee, 2015).

Some group members may decide not to contribute while others may dominate the group. This leads to reduced trust and cooperation within the group (Terry, 2013). An effective collaborative task is one that enables all participants to express themselves and make significant contributions (Rimor et al., 2010). In the view of participation, successful collaboration acknowledges that everyone has ideas to contribute in the collaborative learning (CORP/U, 2013). It is the primary responsibility of group members to (a) support, encourage, and assist one another; (b) hold one another accountable for striving to learn; and (c) ensure that all members learn (Gillies & Boyle, 2011).

The learners intentionally engage in the learning process when creating meaning from their information and experience (Crow & Nelson, 2015). Mthembu & Mtshali (2013) refer to participation by group members as an active 'give and take' of ideas rather than one member passively learning from the others. Encouraging participation ensures that almost all members understand the topic or problem being solved without leaving others behind (Soller, 2001). The group members must accommodate a student who does not understand an answer to a question or solution to a problem by addressing those misunderstandings by providing help to promote effective collaboration (Soller, 2001).

Student participation in a group learning activity cannot be assumed since it is critical to the success of collaborative learning (Liu et al., 2015). The weakest member in the group in terms of participation determines the probability of success, the quality of the solution, and the efficacy in dealing with the group problem (OECD, 2013). Some factors which affect the leaners' participation in group learning are discussed below.

a. **Provision of Equal Opportunities**: Providing equal opportunities to students make them develop a sense of ownership of the newly constructed knowledge (Jonassen, 2000). Otherwise, high-ability students may become more actively involved in the group problem than low-ability students tending to dominate the discussion. Also, some group members may not be willing to participate in solving group problems. By getting a chance to present what they think about the ideas of others and expressing their own ideas, students engage in meaningful discussions which lead to meaningful construction of knowledge (Brooks & Brooks, 1999).

b. **Personal Attributes:** Diaz et al. (2010) noted some challenges faced by individuals in collaborative learning such as worry of individual contributions not being acknowledged or rewarded, whether some members over-contribute while others under-contribute and, whether the contributions by individuals are inadequate or substandard. Collaboration cannot take place when one member becomes dominant and assumes a pre-eminent role. Students' participation may be suppressed by the presence of high achieving peers or members with higher status (Mclaren, 2014). This dominance becomes an obstacle to effective collaboration (Dyke et al., 2012).

c. **Free Riding:** Some students may choose not to participate and be comfortable with the "free ride" status (Mclaren, 2014). This may make active members to reduce their contributions once they realize that others are not giving their best. Karau and Williams (1993) refer to this situation as 'social loafing' where individuals use less effort on a group task while expecting to benefit from the efforts of other group members.

d. **Provision of Informative Feedback:** Mclaren (2014) defines feedback as information that helps affirm or adjust performance, be it formal or informal, and may include positive reinforcement or constructive suggestions on how to get engaged in an activity. Feedback is important in the interaction process since it increases learning and promotes creativity (Cooper, 2014). According to Domalewska (2014), learners who provide feedback perform better than those who do not. Constructive and clear feedback improves the students' learning outcomes (Lee, 2014). Thus, feedback promotes learner engagement if it is appropriately provided (Liu et al., 2015). On the contrary, the students' rates of participation may drop due to the lack of a response or a delayed response (Gikandi et al., 2011). Researchers agree that prompt and timely feedback is vital in collaborative learning (Gedik et al., 2013; Lee, 2014; Lee & Dashew, 2011). A timely response to learners from instructors or fellow group members is one of the factors which encourage participation and its absence lowers participation (Dringus & Ellis, 2010). Untimely response with significant time lags from either peers or instructors discourages participation in discussion forums, and gives a negative effect on the liveliness of the discussion leading to a drop in participation rate (Dringus & Ellis, 2010; Gikandi et al., 2011). Nonresponsive feedback can jeopardize collaborative learning. Thus, collaboration can fail when students fail to seek and obtain help (Nelson-Le Gall, 1992).

According to Davies & Graff (2005), the level of student participation directly affects student performance in terms of grades, with students who attain higher grades having engaged more actively in collaborative learning compared to those with lower grades. Ezeah (2014) measured the level of learner participation using frequency and quality of member contributions. The frequency of contributions can be measured by counting the number of messages and statements submitted by each individual and/or the group. This allows both groups and individuals to be compared in their level of participation (Muuro et al., 2016). Measuring participation in a qualitative dimension is a challenge that has not yet been solved (Rocca, 2010). However, the importance of each contribution varies; for example, viewing a discussion is rated lower than creating a new post, posting a question is more important than commenting on a previous contribution, and an answer with some elaboration is highly rated than a simple answer without an explanation.

While participation in group tasks is essential, it is conceived and its evidence is collected in various ways: from quantitative measures (e.g. the number of messages posted) to qualitative ones (e.g. richer discussion or knowledge construction) (Kirkwood & Price, 2014). The gains from participation in group activities largely depend on how the participants engage actively with peers. While quantitative measures are easy to capture, they give little to understanding how participation can promote effective learning. The measures giving the details of interaction are more informative (Kirkwood & Price, 2014). A participation scale for measuring individual or group participation can be developed from a questionnaire (see Herrmann, 2013).

2.3.3 Group Cognitive Conflicts

Jiangnan et al. (2014) define a cognitive conflict as a contradictory phenomenon between student's cognitive knowledge structure and new information or situation. It is an imbalance resulting from a contradiction of newly acquired knowledge with existing knowledge Moody (2010). The cognitive conflict occurs when one becomes aware of a discrepancy between one's existing cognitive framework and new information or experiences from other sources (Lai, 2011). Thus, group cognitive conflicts arise when the incongruities exist between the learner's (individual) knowledge and the collective knowledge in the group problem (Moskaliuk et al., 2012). Cognitive conflicts are noted when peers argue amongst themselves, clarify and evaluate each other's ideas leading to cognitive restructuring (Snapwiz, 2012). This conflict on knowledge occurs during social interaction as a divergence between the group knowledge and the students' viewpoint (Dillenbourg, 1999). Thus, cognitive conflicts occur in collaborative environments when students learn in a group. Actually, learning is not facilitated by the conflicts, but rather, it is the effort used in elaborating different viewpoints to resolve the conflict which leads to effective learning (Chan & Chan, 2011).

According to Lee and Kwon's model (2001) the cognitive conflict process occurs when a learner (a) recognizes an anomalous situation in the preliminary stage, (b) expresses interest or anxiety about resolving the cognitive conflict in the conflict stage, and (c) engages in cognitive reappraisal of the situation in the resolution stage (Figure 2-3).

Cognitive conflicts on knowledge during collaboration have the potential to stimulate the learning process (Aarnio, 2015). Bao et al. (2013) admits that cognitive conflict is a vital factor in an individual's conceptual change during learning.

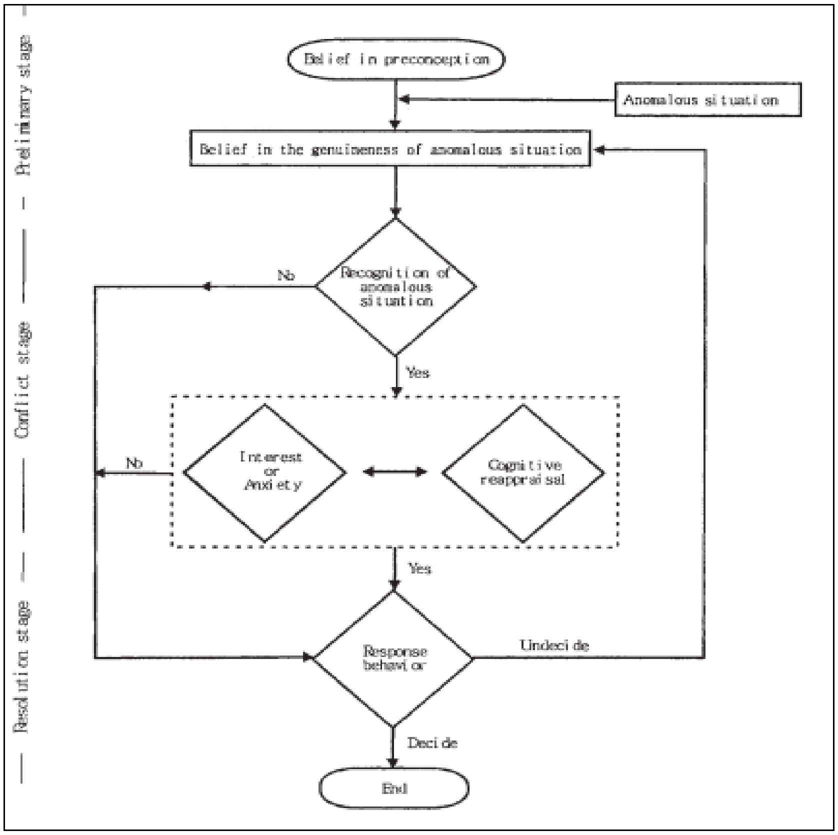


Figure 2-3:Cognitive Conflict Process Model

(Source: Lee & Kwon, 2001)

Cognitive conflicts make an individual to move from his personal learning cycle to social cycle and participate in collaborative learning through interactions (Said et. al, 2015). The cognitive conflicts assist the learner in identifying, challenging and reconstructing likely misconceptions (Aarnio, 2015). Conflicting ideas and knowledge which appear during collaborative discussions motivate the learners to explore, combine and refine each other's ideas and understandings (Aarnio, 2015). Group cognitive conflicts assist to uncover ideas and assumptions from all group members which might otherwise lead to incomplete analysis and improper decisions (Gutbezahl, 2010). The disagreements in terms of knowledge conflicts allow participants to construct explanations, give reasons, and justify their views. Those misunderstandings during collaboration are important since they 'force' group members to provide explanations, give reasons, and justify their positions (Lai, 2011).

The existence of knowledge conflicts raises the need to create a shared understanding of a topic and to refine students' understandings (Dolmans & Schmidt, 2006). Cognitive restructuring takes place when students argue with another, clarify and evaluate each other's ideas and perspectives (Myrseth & Wollbrant, 2015). Students examine conflicting ideas by asking questions that provoke contrasts and comparisons; and that arouses explanations and reasoning which help students attend constructively and critically to each other's ideas (Yew & Schmidt, 2009). Cognitive conflicts are resolved when individual learners adapt their own cognitive structures to the conceptual structure of the artifact in consideration (Cress, 2013).

Group cognitive conflicts on group goals, key decisions, and actions from group members, if properly managed lead to improved decisions and levels of group knowledge (Gutbezahl, 2010). Group cognitive conflicts should be encouraged so long as they don't degenerate into potential relational disagreements (Gutbezahl, 2010). Students must have the ability to disagree without feeling threatened or competing with each other as a major concern in collaborative learning (Butera & Mugny, 2001).

Kieslich and Hilbig (2014) developed a two-stage model based on the learners' self-control when resolving conflicts. Cognitive conflict may emanate both from the successful and unsuccessful resistance to impulse. As shown in Figure 2-4 the learner may or may not identify conflicts (stage 1). Failure to identify a conflict makes the learner to exercise no constraint. On the other hand, conflict identification leads to the use of self-control strategies (stage 2).

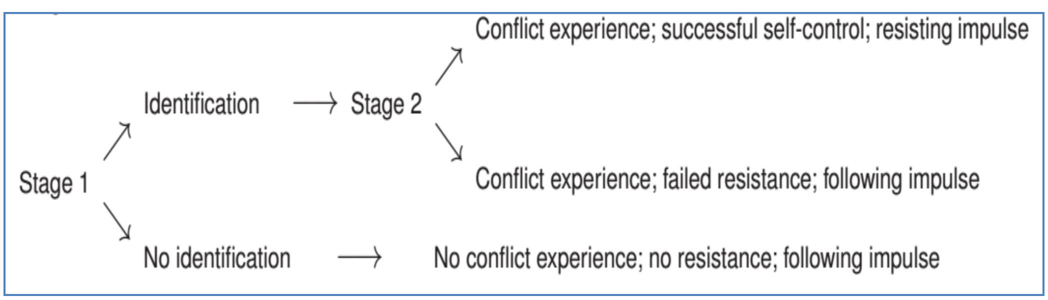


Figure 2-4: Two-stage model of self-control

Source: Myrseth & Wollbrant (2015).

Group cognitive conflicts can be measured for analysis. Lee (1998) rated levels of cognitive conflict from participants in his study using individual interviews. The researcher (Lee, 1998) and two other panelists used a pre-developed rating scale to assess cognitive conflicts using the participants' videotaped individual interviews. The levels of cognitive conflict were double-checked by requesting students to rate themselves using a questionnaire. The statements made by students were coded into one of five possible performance categories. The students were grouped according to two dimensions: (a) amount of conceptual change (none, some, or substantial if their gain in answer score from pretest to posttest was < 25%, 25-50%, and 50% or more, respectively and (b) pretest answer scores (high, medium, or low).

Cognitive conflicts which occur during group discussions have their own challenges on group interactions. When encountered with conflicting knowledge, students may raise the issue or desist (Aarnio, 2015). Improper level of cognitive conflicts can cause difficulties and even endanger the collaborative learning process. For example, if the conflict is excessive, it could lead to withdrawal, anxiety or frustration. An excessive conflict can even break down the learners' current internal structures (Chow & Treagust, 2013). Discussed below are some factors which affect group cognitive conflict.

a. **Improper levels of Cognitive Conflict:** Too little or too much cognitive conflict existing in a group leads to learning problems (Bearison et al., 1986). Too much agreement suppresses relevant and important new ideas which may be introduced and not so relevant ideas being unchallenged (Mclaren, 2014).

b. **Groupthink:** This situation arises when a group agrees to make decisions without taking into consideration all the raised issues and thus avoiding unintended consequences. This happens when members avoid social conflicts (Gutbezahl, 2010). When a group fails to negotiate the meaning of knowledge and opinions gaps among them, they are unable to overcome personal conflicts making the conversation to remain at a superficial level (Jahng et al., 2010). Collaboration becomes elusive when students avoid arguments and conflicts which can lead to misunderstandings and hurt the feelings of their colleagues (Johnson et al., 2000). Students may intentionally evade conflicts (Clarke et al., 2007) as a polite way of avoiding confrontations within the group (Aarnio, 2015) and in order to allow the discussion to continue (Rimor et al., 2010). Students may avoid disagreements if they aim to maintain positive social relationships (Chiu & Khoo, 2003). They fear that differing ideas may lead to negative feelings like tension and uncertainty (Brookfield, 2012).

c. **Personality Dominance and Indifferences:** If the cognitive conflicts are not dealt with within the group, then a single perspective of a dominant person is adopted or a joint hasty decision is made (Aarnio, 2015). Indifferences arise when individuals disregard other learners' contributions by not listening or not asking questions about the views of others (Aarnio, 2015). An indicator is when statements or counter arguments are elaborated by those who brought up the issue, or counter arguments accepted without challenging or elaborating (Van Boxtel et al., 2000).

d. **Lack of Elaboration:** Students may not elaborate their differing contributions due some reasons such as: they may be unaware of their colleagues' alternative perspectives (Johnson & Johnson 2009), they may incorrectly think that they understand and agree with each other if they bring their ideas on the same terms and, they may be unwilling to provide explanations. This could lead to a common misconception that everybody in the group knows what the individuals know (Schmidt et al., 2011).

2.3.4 Promoting Group Interactions

Song and McNary (2011) posit that it is a challenging task to facilitate an effective learning experience through quality student interactions. In online discussion, learners can become passive, less critical and less effective (Chiu & Hsiao, 2010) leading to limited cognitive quality during group interactions (Wang & Hwang, 2012). There exists a variety of behavioral and interaction mechanisms which promote collaborative learning (Webb, 2013). Some of them are discussed below.

a. Active Participation

Effective learning can only be attained when learners take an active role in their own learning, that is, the learning of others and learning together as a group (Griffin et al., 2012). By working in groups students encourage, support, help each other and provide feedback to each other in order to improve their performance. Students interact through cognitive processes such as explaining how to solve problems, teaching each other what they know, linking to prior learning knowledge and experience and facilitating the learning process (Isik & Saygili, 2015). Through collaboration, students articulate their own ideas and evaluate, question, sharpen, or build on the ideas of others, to deepen both students' individual and their collective conceptual understanding (Fischer et al., 2013). According to Healey et al. (2010) the experience of learning by doing is the key idea behind active learning and student engagement.

Since, lack of active participation and interaction by learners make them lose motivation and feel less satisfied (Park & Choi, 2009), there is need to incorporate strategies to encourage students to participate in the learning activity.

b. Use of open-ended questions

The formulation and use of challenging questions promotes group interaction. The use of open-ended questions rather than closed ones increases the quality of collaboration (Webb & Jones, 2009). Learners solving ill-structured problems, which have no absolute solution, must elaborate their views to their group members, and validate their opinions (Soller, 2001).

c. Providing Elaborations and Explanations

Providing information, asking questions, providing answers can be improved when accompanied by elaborations and explanations. An explanation or elaboration, as an interactive process during discussions, benefits both the explainer and the one being explained to. The verbalization of knowledge through members justifying their actions to each other has a positive effect on learning (Jaimini, 2014). Learners themselves understand the learning content better when they provide explanations to help their fellow students understand the material (Howe et al., 2007). This way, they improve their comprehension of concepts leading to shared understanding from negotiated meaning (Lai, 2011). Thus, students who do not provide explanations do not benefit from collaboration as those who do (McLaren, 2014).

d. Provision of Informative Feedback

Collaboration is negatively affected when students fail to seek and obtain help (Nelson-Le Gall, 1992). Student may be unaware of their need for help or, when they are aware of their need, they may seek help that is irrelevant or ineffective (McLaren, 2014). Some students may not seek help for them not to appear “dumb” or dependent on other students (Ryan et al., 2001). Feedback is also important in the interaction process since it increases learning and promotes creativity (Cooper, 2014). According to Domalewska (2014), learners who provide feedback perform better than those who do not.

2.3.5 Suppressing Group Interactions

Collaborative learning can also be suppressed by some of the factors discussed below:

a. Premature Agreements and Disagreements

Group interactions can also be affected by the extent to which students agree or disagree when solving a group problem (McLaren, 2014). Too little or too much agreement reduces cognitive conflicts leading to less knowledge creation. Too much agreement causes relevant and important new ideas not be introduced and incorrect ideas to go unchallenged (McLaren, 2014). Students may sometimes avoid disagreements in order to maintain positive social relationships with each other (Chiu & Khoo, 2003). Students may feel scared or afraid to question ideas of their friends (Liu et al., 2008). Research has also shown that students tend to accept opinions from their group members, not because they agree with them but merely to hasten the discussion (Rimor et al., 2010). On the other hand, too much disagreement leads to a lot of wasted time through fruitless arguments with no new ideas being introduced or accepted by group members.

b. Improper coordination of group tasks

Well-coordinated groups allow participants to listen to each other’s ideas and build upon them (McLaren, 2014). Lack of proper coordination during group problem solving leads to disorganized engagements, with learners not taking turns to listen to each other, rejecting proposals for others, and only advocating for their own ideas and contributions (Barron, 2000).

c. Negative social behaviors

Negative social behaviors such as rudeness and unresponsiveness or ignoring each other make the quality of the collaboration to suffer (Chiu & Khoo, 2003).

In conclusion, McLaren (2014) advocates for the restructuring of collaborative learning in order to realize the behaviors that promote collaboration which are typically not present (or erratically present), and eliminate the suppressive behaviors which are very common in collaborative learning. However, the implementation of behaviors to promote collaboration and to eliminate the suppressive ones is a big challenge.

2.4 Collaborative Knowledge Construction

2.4.0 Introduction

Collaborative learning requires that participants jointly construct knowledge and be aware of the group processes in order to gain from the collaboration (Blake & Scanlon, 2012). Knowledge construction takes place within a collaborative environment (Said et. al, 2015), since knowledge is created collectively (Kimmerle et. al 2011). Knowledge construction itself is an outcome of collaborative learning (Shukor et al., 2014), and evidence that collaboration took place (Alavi & Dufner, 2005). Mthembu & Mtshali (2013) define knowledge construction as mental act of both acquiring new knowledge and communicating existing knowledge. Based on the constructivist theory, learning occurs when learners are actively engaged in the process of knowledge construction supported by multiple perspectives facilitated by social interactions, as opposed to just being passive recipients of knowledge (Bhattacharjee, 2015). Thus, construction of knowledge is only effective in collaborative learning environments (DeWitt et al., 2014). Knowledge construction can only take place in conditions where collaboration is successful so that effective learning can be attained (Blake and Scanlon, 2013).

The students are able to generate new ideas through interactions (So et al., 2012). This allows for exchange of knowledge at higher degree of thinking leading to knowledge creation (Rogers et al., 2010). Knowledge is created through interactions, as a joint undertaking during collaborative learning (Damşa, 2013). Knowledge construction involves collective inquiry by the participants through dialogue and interactive questioning leading to continuous improvement of ideas (Zufferey et al., 2010). Knowledge construction occurs when a learner disagrees with a partner's conception or identifies an error in his/her thinking, but by justifying it. A student may also refine another student's idea by attempting to reconstruct the solution (Prata et al., 2009). Thus, knowledge construction can only take place when learners exchange ideas, viewpoints and arguments as they discuss a group problem (Mthembu & Mtshali, 2013). The group members need to explain, compare, synthesize, and connect different ideas together (Stahl et al., 2014), through interactions (Mthembu & Mtshali, 2013).

The dialogue within which the learners discuss the group problem is vital for creation of shared meanings and understandings (Peterson, 2010). Meaningful learning can only be experienced when learners attain high-level of knowledge construction. According to Shukor et al. (2014), learners construct knowledge in various levels in a collaborative environment through sharing and comparing opinions (low-level construction), negotiating on shared information (high-level construction) and augmentation (higher-level construction). Argumentative knowledge construction takes place when group members clearly explain their suggestions by giving reasons of how they carry out task and solve problems (Noroozi et al., 2013).

2.4.1 Phases of Knowledge Construction

The process of knowledge construction begins when group members are presented with a real problem, with the process of solving the problem observed throughout the knowledge construction process (Mthembu & Mtshali, 2013). According to Windschitl (2002) knowledge construction process begins within the cognitive structure of every individual and then collaboratively constructing knowledge with others through social interactions. This is in agreement with Zufferey et al. (2010), who view knowledge building in collaborative learning as made up of two major steps: internalization and externalization. First, individuals internalize the shared information into their mental schema which could lead to modification of the knowledge according to their experiences and prior knowledge (Zufferey et al, 2010). Learners construct their own understanding and knowledge through learning experiences and reflecting on those experiences (Bhattacharjee, 2015). Individual learners make sense of information they perceive with each learner ‘constructing’ his/her own meaning, by connecting new ideas to existing ideas on the materials/ activities presented to them” (Bhattacharjee, 2015). A conceptual change, which is essential for meaningful learning, occurs when the individual learners construct their own knowledge by modifying their conceptual framework (Chow & Treagust, 2013). Externalization involves sharing the knowledge with others (Zufferey et al., 2010). This is also referred to as ‘knowledge co-construction’ and involves high-level interactive processes where information is shared by pooling together different pieces of information from multiple sources (Näykki, 2014). In the context of collaborative learning, learning becomes a collaborative process of knowledge co-construction (Damşa, 2013). Learning takes place when learners accommodate their mental models by internalizing knowledge from different views. This involves synthesizing new ideas by integration of newly constructed knowledge with prior experience (Zufferey et al., 2010).

New knowledge is created by students when they actively engage in construction of an external, shareable artifact that helps them to reflect and collaborate (Fessakis et al., 2013). Students can attain high-level knowledge construction by externalizing their thoughts through arguments, justification, or decision making, which encourage critical thinking thereby constructing new knowledge (McLoughlin & Luca, 2000). Students continuously engage in knowledge co-construction until they reach a common understanding of the matters at hand (Mthembu & Mtshali, 2013).

Stahl (2011c) developed a similar model to that of Zufferey et al. (2010) for collaborative knowledge building consisting of two main cycles: personal and social knowledge building cycles. Personal cycle is the tacit pre-understandings of the individuals while the social cycle involves the interactions in the social context during group knowledge creation. It is easy to track the social learning cycle through its phases in the collaborative learning environment compared to the personal cycle. The social learning cycle has the following phases: (1) Articulation phase - group members express their thoughts using any form of thoughts expression, e.g., words or annotations or even nonverbal cues, (2) Alternative discussion phase - involves modification of the articulations from the previous phase through argumentation, (3) Meanings clarification is the third phase, where group members interact to repair any misunderstandings to ensure shared understanding, (4) the fourth phase, perspectives negotiation, is important for members to reach consensus leading to collaborative knowledge building, and (5) Formalization is the last phase in social learning cycle which ensures that the built collaborative knowledge base is maintained in a format that enables group members to commence their personal learning cycle by interpreting the created artifacts and using them to shape their personal understanding. At times it is difficult to clearly differentiate the three intermediate phases of alternative discussion, meanings clarification and perspectives negotiation, since they can be performed using the same set of actions (Said et al., 2015). The group members get involved in interactions containing alternatives discussion, meanings clarification and perspectives until they reach a consensus. However, they postulate that the three phases can be differentiated by the output of the interactions. If the output is reasoning or understanding the reason behind articulated thoughts, then these sessions can be classified to belong to alternatives discussion phase. If interactions are meant to reach a common ground, then these sessions can be classified to belong to the meanings clarification phase. Finally, if the group members interact to reach the final group opinion about a topic of interest, then these sessions can be classified within perspectives negotiation phase.

Blake and Scanlon (2012) identify the components of joint knowledge construction as flow of proposals, questioning, building common ground, maintaining a joint problem space, establishing inter-subjective meanings, positioning actors in evolving roles, building knowledge collaboratively, and solving problems together.

The above models agree in the sense that learners individually and collectively construct meaning during group learning (Bhattacharjee, 2015). This leads to collective construction of knowledge which takes place amongst the group members (i.e knowledge co-construction). Damşa (2013) identified three important aspects for knowledge co-construction: 1) requirement for specific types of interaction, that is, productive interaction, 2) need for elaboration during sharing of knowledge objects which emerge from interaction, and 3) active and deliberate participation in the joint construction of knowledge objects.

2.4.2 Analyzing Group Knowledge Construction

Collaborative learning can be assessed in terms of the collaborative processes and/or the learning outcomes such as learning scores (product). The main problem with assessing collaborative learning using learning outcomes is that it ignores important factors in learning such as motivations, perceptions, attitudes, and satisfaction of students. Assessment in collaborative context can fulfill different purposes, for example, group processes such as co-construction of ideas, conflict, giving and receiving elaborated help, and equality of participation could be encouraged if the aim is to measure students' ability to learn from collaboration. Thus, assessment in collaborative learning should be aligned with the intended goals.

According to Strijbos (2011), collaborative assessment can (a) target the individual and group-level by including both the collaboration process and/or product, (b) be conducted during and after a collaborative learning event, and (c) promote learner's cognitive, social and motivational skills. Figure 2-5 shows two types of evaluations (individual and group-level) which complement each other by allowing individual achievement to be encouraged while promoting a culture of shared learning (Diaz et. al, 2010).

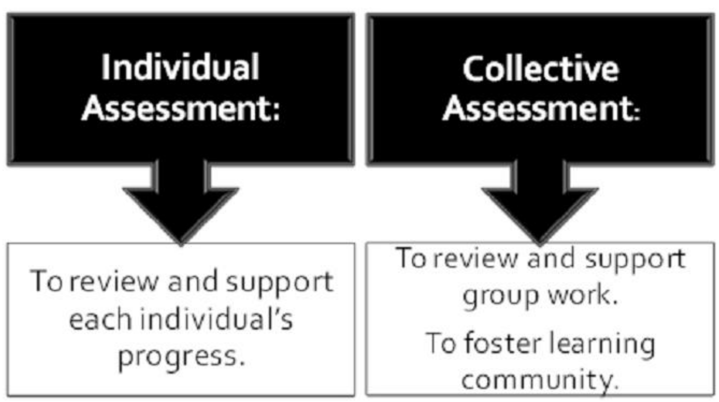


Figure 2-5: Collaborative Learning Assessments

Source: Diaz et al. (2010)

This type of assessment by Diaz et al. (2010) is comparable to the work by Gress et al. (2010) who summarized the measurement of learning in CSCL into three categories: measuring of individual's learning process and outcomes based on individual's experience, measuring the individual learning process and outcomes based on the contributions to the group, and measuring group's learning process and outcomes.

Gress et al. (2010) summarized the measurement of learning in CSCL into three categories: a) measuring of individual's learning process and outcomes based on individual's experience, b) measuring the individual learning process and outcomes based on the contributions to the group, and c) measuring group's learning process and outcomes.

The learning outcomes of collaboration depend on the extent to which group members engage in productive interactions (Dillenbourg et al, 2009). Since assessment drives learning, linking assessment to interaction in creative and strategic ways is important in motivating collaborative learning (Stahl, 2011a). The assessment of collaborative learning should capture the quality of learning both in terms of learning process and product (Strijbos, 2011). This is in agreement with Meier et al. (2007) who argue that the outcome measures of collaborative learning should capture both the group performance and the quality of collaboration. Again, Noroozi et al. (2013) advocate for use of qualitative techniques in addition to quantitative approaches for an in-depth assessment of collaboration process.

Specific collaborative skills can be measured using statistical methods based on observable features such as the number of turns taken during communication, how resources and ideas are shared, how members refrain from interrupting other team members, absence of negative characteristics such as social loafing and abusive language, and so forth (von Davier & Halpin, 2013). The quality of collaborative learning can be measured through the analysis of collaboration processes and group performance. Collaborative processes are measured using content analysis of the member contributions towards the group task or through a questionnaire (Chanel et al., 2013).

The level of knowledge construction can be measured using quantitative or qualitative measures. A quantitative analysis of interactions involve measures such as the number of learner contributions, number of hourly accesses for a group in an activity, contributions of a group, evolution of a discussion, etc. (Shukor et al., 2014). Qualitative analysis deals with evaluation of the collaborative learning process, that is, whether collaborative learning has occurred or not. The processes that take place both during collaborative learning and before the learning outcome is achieved are important (Shukor et al., 2014). Analysis of patterns of work in collaborative interactions can give more understanding on how students construct knowledge (Shukor et al., 2014).

Soller (2001) used characteristic sequences of learner interaction that leads to productive learning to analyze knowledge construction. While such analysis identifies the number of questions and explanations made by each learner, further analysis may associate an explanation as a response to a certain question, or establish whether the explanation satisfied the one who asked the question (Shukor et al., 2014). But, the exploration on the influence on message postings (during discussion) on the overall knowledge construction process is yet to be investigated (Wise & Chiu, 2011). The analyses of knowledge-building discourse can show how students' working together can contribute to each other's understanding, where students takes up each other's ideas (Stahl et al., 2014). Palonen & Hakkarainen (2000) qualitatively analyzed interactions using student's comments, which were partitioned into ideas. One advantage of the analyses of knowledge-building discourse is that it can identify the contributions made by students towards the understanding of their colleagues in the group (Stahl et al., 2014).

2.4.3 Content Analysis for Knowledge Construction

Different studies have used different ways to analyse collaborative interactions since different analysis methods give different information and interpretations (Roseli & Umar, 2015). Content analysis is one of the most common methods used in analyzing the students' contributions (messages) in an online group discussion. Quantitative content analysis involves counting textual elements without considering the syntactical and semantic information embedded in the text (Weber, 1990), while qualitative content analysis is a subjective interpretation of the content of text data through the systematic classification process using a coding scheme and identifying themes or patterns (Hsieh & Shannon, 2005). In qualitative content analysis, textual data are segmented and coded following some predefined rules (Damşa, 2013).

Qualitative content analysis is widely used in analysing the level of knowledge construction acquired by students since it characterizes the meaning of message content in a systematic and qualitative manner (George, 2013)**.** Qualitative content analysis allows for a deeper understanding on the quality of social interaction which the students get involved in during the process of learning and knowledge co-construction (Durairaj & Umar, 2014). Qualitative content analysis is the most common method used in analyzing knowledge construction and involves the following stages: (a) assigning a unit of analysis to the posted messages, (b) coding the messages using a coding scheme and, (c) drawing a conclusion from the findings (Shukor et al., 2014). Students' discussion groups can then be categorized into levels of knowledge construction such as having high or low level (Van der Meijden, 2005). A more detailed qualitative content analysis involves the following steps: (i) Preparing the data into written text before analysis begins, (ii) Defining the unit of analysis as the basic unit of text to be classified by unitizing the messages - differences in the unit definition can affect coding decisions as well as the comparability of outcomes with other similar studies (De Wever et al., 2006), (iii) Developing categories and a coding scheme from data, previous related studies, and theories, (iv) Testing the coding scheme on a sample of text, then checking the coding consistency though inter-coder agreement. This is used to redefine categories and revise coding rules if the level of consistency is low, (v) Coding all the text when sufficient consistency has been achieved, and if possible add new themes and concepts which emerge during coding, (vi) Assessing the coding consistency to recheck the consistency of the coding since human get tired from fatigue leading to mistakes as the coding proceeds, (vii) Drawing conclusions from the coded data by making inferences and presenting the reconstructions of meanings derived from the data, and (viii) Reporting methods and findings.

In content analysis, the unit of analysis is the major entity that is used the data content. In determining the unit of analysis in posted messages, each message is categorized into any of the knowledge building phases, depending on a specific coding scheme. One knowledge building entity contains many coded posts (statement/sentence/paragraph) and, one posting may be categorized into one or more phases. Two or more raters are required to do the coding. As such, postings on disagreed areas need to be coded collectively and a decision made on which one to use. This requires all the raters to come together to do the coding and agree on areas where there are disagreements. According to Chi (1997) there are two types of rater discrepancies: when raters have firm stand on the code to be used on particular posting, and; when raters have different codes but they are not certain which one to use.

Various models which use content analysis classify the messages posted by group members and assist in analyzing the level of knowledge construction. Some of those models are discussed below:

a. Interaction Analysis Model (IAM)

Gunawardena et al. (1997) developed the Interaction Analysis Model (IAM) for evaluating knowledge construction (Table 2-1).

Table 2-1: Gunawardena et al. (1997) Interaction Analysis Model

	Phase	Operation
1	Sharing/comparing of information	Statement of observation or opinion; statement of agreement between participants; identifications of problems.
2	Discovery and exploration of dissonance	Discovering inconsistency of ideas, concepts, or statements, identifying areas of disagreement, asking and answering questions to clarify disagreement or inconsistency among participants
3	Negotiation of meaning/co-construction of knowledge	Negotiating meaning of terms or ideas, and suggesting new construction on issues where conflict exists
4	Testing and modification of proposed against synthesis or co-construction	Testing the proposed new knowledge against existing cognitive schema, personal experience or other sources
5	Agreement statement(s) / application of constructed meaning	Summarizing agreements, applications of new knowledge, and students' self-reflective statement(s) that illustrate their knowledge or opinions have changed

It has five phases namely: (i) Sharing/comparing information (Phase I), (ii) Discovery of dissonance (Phase II), (iii) Negotiation of meaning (Phase III), (iv) Testing and modification (Phase IV) and (v) Application of newly constructed knowledge (Phase V). All discussion messages are analyzed using the five phases of knowledge construction, with phase I and II ranked as lower mental phases, and phases III, IV and V rated as higher mental functions.

According to Moore and Marra (2005), most learning activities during group discussions take place in Phases I and II of the IAM, without reaching the upper phases of negotiation and construction, or testing and application of new knowledge. Chai and Khine (2006) reported a distribution of 60, 20, 13, 4, and 3% from phase I to V respectively and Schellens and Valcke (2005) reported a distribution of 52, 14, 33, 1.2, and 0.4% from phase I to V respectively. This raises the need to motivate learner by encouraging them to participate and guiding them through the learning process. This can lead them into higher phases of interaction, which are difficult to achieve, leading to higher levels of knowledge construction.

b. Practical Inquiry Model (PIM)

This model, proposed by Garrison et al. (2003) stipulates that education is the collaborative reconstruction of experience. According to this model, higher order critical thinking is only achieved when an educational experience is entrenched in a social interaction environment. The model has four phases namely: the triggering event, exploration, integration and the generation of a solution or hypothesis to a problem. The phases might form a cycle with solution or hypothesis producing further problems and triggering new events.

In their comparison between IAM and PIM, Lu and Jeng (2006) suggested that IAM is stronger than PIM because it identifies more specific types of cognitive activities in critical discourse such as argument, resource and evidence of changes. They posit that IAM gives researchers more specific codes to investigate the knowledge construction process, and provides a holistic view of the discussion flow.

c. Gweon Coding Scheme

This coding scheme for analyzing group feedback consists of five mutually exclusive categories: (R) Requests Received, (P) Help Provision, (N) No Response, (C) Can't Help and (D) Deny Help. In Request Received (R), help requests are conversational contributions such as asking for help on problem solving, asking an explicit question about the domain content, and expressing confusion or frustration. Questions asking about coordination issues are not coded as help requests. The other three categories are made of responses to questions in Request Received (R) category. Help Provisions (P) attempt to provide support or substantive information related to other student's request, regardless of the quality of this information, and aim to resolve the problem. Can't Help statements (C) are responses where from other student indicating they cannot provide help because they do not know what to do. Deny Help (D) statements consist of student responses showing unwillingness to provide help even when knowing the answer. And finally, No Responses (N) are statements where the other student ignores help requests completely.

d. Other Content Analysis Models

Veerman and Veldhuis-Diermanse (2001) developed a content analysis model based on social constructivist principles. It identified two main discussion behaviors, namely task-oriented and non-task-oriented communication.

The coding scheme by Webb (1991) is based on types of student communication as well as their group behavior. The author differentiates responsive and nonresponsive feedback during collaborative work. Responsive feedback consists of essential corrections, elaborations, and explanations.

In conclusion, the type of content analysis to be undertaken depends on the kind of collaboration and the quality of the interaction being measured. An existing tool for analysis, a new one or a modified one can be used depending on the study.

2.5 Facilitating Collaborative Interactions for Knowledge Construction

2.5.0 Introduction

According to Näykki (2014), effective collaborative learning takes place in presence of knowledge co-construction, and not merely information sharing. Collaborative learning requires that participants jointly construct knowledge and be aware of the group processes in order to gain from the collaboration (Blake & Scanlon, 2012). Students mutually create knowledge through collaborative learning (Cooper & Cowie, 2010), based on the way they work on the learning task together (Fischer et al., 2002) and how they construct arguments (Leitão 2000).

It is a collaboration requirement that participants become aware of the group processes when jointly constructing knowledge (Blake and Scanlon, 2012). The processes which the group members engage in during collaboration facilitate collaborative learning (Näykki, 2014).

Even though collaboration is beneficial for learning, successful collaboration is evasive and positive learning outcomes are not definite (Näykki, 2014). Learners need to be encouraged to engage each other during collaborative learning in order to create new knowledge (Durairaj & Umar, 2014). It is important to come up with new approaches to improve collaborative learning (Hämäläinen & Vähäsantanen, 2011). The collaborative learning environment should be one that enables students to be proactive and independent in their collaboration (Chan & Chan, 2011). Collaboration does not occur naturally and the students may not have a suitable understanding of the collaboration requirements (Reed, 2014). However, the identification of the requirements for successful collaboration is not a guarantee for collaboration. Thus there is need to facilitate group interactions.

Ferschke et al. (2015) postulated how the process of knowledge construction can be facilitated by a teacher through requests for explanations and inferences followed by their elaboration.

2.5.1 Facilitating Group Interactions

Grouping individuals into collaborative learning groups does not translate into effective interactions or collaborative learning (Weinberger et al., 2005). It is challenging to 'create' collaboration (Dillenbourg & Jermann, 2010), and also relatively rare to attain high-level, productive collaboration (Hämäläinen, 2011).

The difficulties in collaboration are as a result of poorly designed learning activities, and problems with communication and organization of those activities within the collaboration environment. Students require guidance on how to interact (Ruiz-Primo et al, 2011), and the facilitation of collaborative interaction leads to better and effective collaborative learning (Kim et al., 2014).

Knowledge construction can be enhanced within group discussions and debates by encouraging constructive arguments (Zhu, 2012). Researchers continue to formulate instructional approaches to guide and improve collaboration processes and thus collaborative learning (De Wever et al., 2010). Discussion forums have been used a way of promoting peer interaction and collaborative learning in online environments (Xia et al., 2013). Instructor-to-student interaction has been implemented by facilitating discussions (Kim et al., 2014), coordinating collaborative learning, or providing supportive information (Gedik et al., 2013). Roschelle and Teasley (1995) identified various conversational strategies used in discussions to allow students reach deep levels of collaborative interaction for attainment of shared understanding which include taking turns, socially distributed productions, repairs, narrations, and nonverbal actions or gestures. Groups requiring help can be supported in terms of interaction, communication, negotiation, co-construction and revising knowledge (Hmelo-Silver & Barrows, 2008).

Group facilitation is a skill which empowers and enables a group to generate ideas and complete a group task (Vivacqua et al., 2008). It provides a structure for the group activity, establish time limits, maintain group order, ensure that everyone is heard, encourage creativity, answer questions, and collect reports as needed (Terry, 2013). Group facilitation is instrumental in shaping a discussion and thus affecting the students' knowledge construction (Hew & Cheung, 2011). There is need to facilitate the learning experience through quality learner interaction and engagement (Song & McNary, 2011). Most of the collaborative learning facilitation largely focuses on techniques used by tutors or instructors (Hew & Cheung, 2011). A constructivist learning strategy would facilitate the students’ creation of their own knowledge while they are given more liberty to reflect on the group problem together and to generate original ideas (Mthembu & Mtshali, 2013). For example, students can be provided with learning material containing conflicting evidence (Valleala et al., 2010) or by assigning them conflicting roles. This forces the members to explain their different views, argue their positions and negotiate to reach a joint solution (Sandoval & Reiser, 2004). A human facilitator may identify some conditions such as one or more member dominating a discussion, a participant retreating from a group discussion, and members making unsubstantiated claims (Ding et al., 2007). When such is noted the facilitator can intervene to improve the discussion.

Soller et al. (2004) summarized the methods of supporting collaborative learning into three: (1) identifying the collaborative joint work activities and presenting them to participants so that they can understand their collaborative acts; (2) monitoring and modeling all interactions among the learners and noting differences between the ideal state and the current state; and (3) analyzing the state of collaborative learning and providing advice for effective collaboration. In their study, Lu and Jeng (2006) identified some important facilitation techniques used by instructors to enhance knowledge construction including (i) identifying areas of agreement/disagreement, (ii) seeking to reach consensus/understanding, (iii) encouraging, acknowledging, or reinforcing student contributions, (iv) focusing the discussion on specific issues, (v) confirming understanding through assessment and explanatory feedback, and (vi) diagnosing misconceptions.

It is interesting to note that the discussion platforms in Learning Management Systems do not automatically promote or facilitate knowledge construction (Zingaro, 2012). The same applies to mobile learning management system. Since mobile devices are meant to facilitate learning interactions (Power, 2013) proper mobile learning design need to emphasize the learners' interactions (Sharples et al., 2009) for effective learning to take place. However, the design support for collaborative m-learning, especially the processes of collaboration, and the design for conditions necessary for fostering and promoting effective collaboration is a big concern (Nouri, 2011).

Students require guidance and support in order to cope with learning issues arising from collaborative learning (Mthembu & Mtshali, 2013). Learners need to be encouraged to engage each other during collaborative learning in order to create new knowledge (Durairaj & Umar, 2014). Designing activities that involve interaction and collaborations requires a lot of effort to manage the group interactions (Stahl, 2011a). The design of the students' discussion task influences the levels of knowledge construction and thus it is important to design tasks which leave enough room for discussion (Hew & Cheung, 2011).

The next two sections give detailed explanations on the two types of facilitations for collaboration, namely facilitation for group participation and regulation of group cognitive conflicts.

2.5.2 Facilitating Group Participation

Participating in group discussions is of primary importance for active knowledge construction through interaction with others (Noce et al., 2014). According to Khalsi (2012), knowledge construction can be improved by encouraging students' participation in the collaborative interaction. Bassani (2011) points out the need to actively promote participation in collaborative learning. There is need to design collaborative learning environments which encourage students to participate in shared knowledge-construction processes (Hämäläinen & Häkkinen, 2010). An effective discussion forum should actively promote student participation (Bassani, 2011) and provide learner with motivation by dealing with the danger of isolation and disconnection (Rovai, 2007).

Discussed below are two approaches to facilitate group participation, namely (i) informative feedback and (ii) turn taking.

a. Informative Feedback for facilitating Group Participation

Feedback is a type of help provided in collaborative learning process. This help can be offered by the group members to each other or provided by the facilitator, can be unintentional help provided as a byproduct of collaborative processes or can be fully intentional (Cui et al., 2009). Informative feedback is a suitable way to encourage quality participation and interaction to facilitate knowledge creation (Gikandi et al., 2011). Timely feedback is critical for facilitating a comfortable learning environment (Lee & Dashew, 2011) and should assist participants to improve their contributions (Abawajy, 2012).

According to the constructivist theory, the instructor's intention is to intervene during the learning process and not to take charge of the process; so should feedback be (Flórez & Sammons, 2013). The instructor needs to closely monitor and provide immediate feedback to students for realization of successful collaborative learning (Chen, 2007). Automatic feedback enables the instructor to intervene in the learning process or the collaboration, to improve the impact of collaborative learning (Kosba et al., 2007). The instructor encourages the students through questions, challenging their ideas and even formulating the idea to reach the conclusion (Ültanır, 2012).

Other than motivating the students, feedback can also be provided about the student participation in a collaborative environment (Dingel et al., 2013). Being able to measure engagement (participation) assists the instructor to provide appropriate feedback (Liu et al., 2015). For example, low engagement can be improved through encouraged participation. Any imbalance in student participation can be easily noted by monitoring the students' engagement in group activities. This not only facilitates intervention by the instructor, but also for the students to gauge themselves and improve their engagement (McLaren, 2014).

Often, students are not aware of their need for help or when to seek help that is relevant or effective (Mclaren, 2014). Also, some students may not want to appear to be dependent on their group members or look "dumb" (Ryan et al., 2001). McLaren et al. (2010) developed techniques to automatically evaluate collaborative arguments and provide feedback to students and alerts teachers on some of these conditions so they can intervene and guide student discussions.

b. Using Turn Taking to facilitate Group participation

High quality interaction requires that students participate equally in the discussion (Lindblom-Ylänne et al, 2003). Equal opportunity to participle is a key factor determining group's ability to solve problems, create ideas and make decisions (Woolley et al. 2010). For example, group members may not take turns to pay attention to the contributions made by their peers, may dismiss proposals and contributions without careful consideration, or may only push for their own ideas to the discussion (Barron, 2000).

Turn taking is a collaboration rule which encourages opinion sharing and equal participation. Turn taking is a group facilitation which uses turn allocation techniques for selecting the next contributor to the group task (Sidnell, 2010). Turn taking is a fundamental feature during conversations and is an organized and co-ordinated activity which minimizes overlaps when people are interacting, or any gaps where no-one contributes. Turn taking may use a round robin strategy where every group member is provided with an opportunity to make a contribution about an issue (Terry, 2013)**.** For example, everyone is presented with a chance to present his/her ideas (Beasley & Jenkins, 2003). Those without any contributions to make can 'pass' the opportunity to the next person. The group members can use their opportunity to question, clarify and reword their peers' contributions to confirm their own understanding of the team's interpretation of the problem and the proposed solutions (Soller, 2001). Thus, turn taking ensures that there is no group domination because everyone gets an equal chance to contribute (Beasley & Jenkins, 2003).

2.5.3 Regulating Group Cognitive Conflicts

The social interactions amongst students play a critical role in the processes of learning and cognition (Mthembu & Mtshali, 2013). Higher level of knowledge building and successful conceptual change exist in learning situations where cognitive conflict is maximized (Chan et al., 1997).

Resolving of conflicts on knowledge is important for the constructive and collaborative tasks during learning (Aarnio, 2015). The ability to resolve conflicts during collaborative learning determines how well group members are able to create a shared understanding of a topic (Johnson & Johnson, 2009). Since these cognitive conflicts emanate from the individual students with differing interpretation and understandings, dealing with these conflicts is perceived as a knowledge construction process whereby ideas are processed to achieve a deeper understanding (Aarnio, 2015). However, not much research has been done on how students deal with conflicts on knowledge which arise during collaboration, and how they can be facilitated (Aarnio, 2015). The difficulty in reaching a consensus becomes a major challenge in attaining effective learning (Rimor et al., 2010).

It is crucial to know how to deal with conflicts on knowledge in a collaborative learning (Aarnio, 2015). The way those conflicts are dealt with and the ability to resolve them affects group learning (Hall & Weaver, 2001). Differences exist on how low and high achieving students deal with cognitive conflict. High achieving students are comfortable with cognitive conflicts, while low achieving students try to avoid them (Dreyfus et al., 1990). Some low achievers view cognitive conflict as failure on their part.

There are two types of facilitations for regulating group cognitive conflicts, namely Role Playing and Guided Negotiation, discussed below.

a. Regulating Group Cognitive Conflicts using Roles

Roles often arise during collaborative learning which determine the interaction and the learning outcomes. The interaction which is built during collaboration through questions, critique, and requests for clarification or justification often influence how the roles emerge (Strijbos & De Laat, 2010). Through roles, group members assume responsibilities on themselves or others by positioning themselves or others, or in response to others' positioning moves (Sarmiento & Shumar, 2010). When a group member is limited to a single role, the multiple functions that the member can perform are ignored (Chiu, 2000).

Role-playing increases interactions during knowledge construction in collaborative discussions (Deiglmayr & Rummel, 2015). When participants take new roles differing from what they are, they get encouraged to look at the problem from a different perspective. Assigning of roles is meant to improve students' engagement with each other towards successful collaborative learning (Hou, 2012). Also some members may feel free to express themselves when they "hide" behind a role (Gustavsson, 2002). De Wever (2010) identified the importance of roles in group discussions: they 1) support the process of group negotiation when resolving cognitive conflicts, 2) coerce students to concentrate on their responsibilities and content of their contribution, and 3) increase the participants awareness of collaboration.

Students in group learning can play different roles such as source searcher, theoretician, summarizer and moderator (De Wever et al., 2008). Others may emerge as leaders, activity coordinators, and so on (Dornfeld & Puntambekar, 2015). Of importance is to note that the patterns of roles as they emerge determine the learning efficiency (Spada, 2010) and the group's depth of knowledge co-construction (Gu et. al, 2015). Leadership, which emerges during group interaction, can be dynamically distributed among group members. Group processes and collaborative knowledge building are driven, to an extent, by the different leadership moves made by different individuals in the group (Stahl et al., 2014). Persell (2004) categorized student roles into starters (they question, raise issues and reflect on learning materials), responders (they answer questions and post new questions), and facilitators (they tutor, introduce new learning sources and administer discussion). Other roles may include facilitator, proposer, supporter, critic and recorder. A facilitator invites participation, monitors the group's progress, and promotes group harmony (by tempering conflicts, building compromises, etc.). A proposer suggests new ideas. In response, supporters and critics evaluate it, seeking advantages and disadvantages. A supporter tries to justify the claim and elaborate it. In contrast, a critic challenges the original claim and identifies weaknesses. The recorder summarizes the group's progress.

Roles can be assigned by an instructor or the students can decide amongst themselves (Hou, 2012). Assigning roles in a rotational way ensures that someone is designated to take care of a vital group function at any given time (Toseland & Rivas, 2005).

b. Guiding Group Negotiation to regulate Cognitive Conflicts

Ignoring conflicts leads to poor decisions while healthy interchanges on conflicting ideas result to sound decisions. Garmston and Zimmerman (2013) argue that collaboration cannot be realized unless conflicts are tackled as a creative source of knowledge construction. They identified some important considerations which are helpful in resolving conflicts. They include: (i) learner's need to know how their behavior can contribute to or even escalate the conflict, (ii) categorically stating the conflict as it is to allow for ideas to resolve it, and not divert to people, (iii) summarize different viewpoints to avoid overworking the conflict, and (iv) communicate the issues more coherently when they disagree (agree to disagree).

According to Stahl (2011b), group knowledge negotiation is crucial in collaborative learning and specifically in collaborative knowledge building. Stahl (2011b) views negotiation, not simply as a reconciliation of multiple opinions, but as process of collaborative construction of new knowledge based on interaction and discourse, rather than the selection of an opinion among alternatives. Through negotiation, group members adopt new shared goals, in turn leading to broader shared understanding (Puntambekar & Young, 2003).

Learning is not facilitated by the conflicts, but rather, it is the effort used in elaborating different viewpoints to resolve the conflict which leads to effective learning (Chan & Chan, 2011). Negotiation and reaching consensus is affected by many factors including power disparities that resist effective negotiation. However, the efficiency of negotiation is dependent on mutual understanding, effective dialogue and communication between all group members. These factors which affect negotiation make the most subtle phase in knowledge-building (Said et. al, 2015).

Emphasis needs to be placed on the learning experiences within collaborative environment to enable members to reach a shared understanding (Liu et al., 2015). According to Hamdan and Schaper (2012), the use of interaction rules may help in regulating a discussion (e.g. each member can come up with three ideas). Learning facilitations can be provided in terms of tightly structured processes to direct the conversation and guide group negotiation (Garmston & Zimmerman, 2013).

2.6 Computing Intelligence and Collaborative Learning

2.6.0 Introduction

According to Filigree Consulting (2012), technology is an important enabler for improving student learning outcomes. Kirkwood and Price (2014) define technology enhanced learning (TEL) as the application of information and communication technologies to teaching and learning. Technology tools have been used to enrich the learning materials used with multimedia elements, to easily carry the materials created to the classes, to share with students, to make corrections, to make materials comply with the situation and the requirements, to provide more effective learning for students by establishing material-student interaction, to facilitate classroom management, to increase interest and curiosity of the students to the subject of the lesson and to improve their attitudes towards the course (Isik & Cukurbasi, 2012)

An important technological goal in the field of CSCL is to develop environments with affordances that support effective collaboration (Adamson et al., 2013). A series of studies in the computer-supported collaborative learning field demonstrate the pedagogical value of social interaction from a cognitive perspective, showing that interventions that intensify argumentative knowledge construction, in support of group knowledge integration and consensus building, enhances the development of multi-perspective knowledge (Weinberger et al., 2007).

There is much room for use of technology in collaborative learning (McLaren, 2014). In collaborative learning, technology has been used to facilitate teacher's planning, intervention and tracing the learning process with respect to the usage of resources (Isik & Saygili, 2015). Mallon and Bernsten (2015) identified collaborative learning technologies ranging from communication tools that allow for synchronous and asynchronous chats to online spaces that facilitate brainstorming, document editing, and remote presentations of topics. Lomas et al. (2008) differentiated collaboration tools from online communication tools as those which should encourage communication among participants, with easy interfaces to use, and be capable of collaboration. Collaborative learning tools exist for group idea generation and brainstorming such as Google Docs, Padlet, Mindmeister, and Lino (Hovious, 2013) with space for multiple participants to collaborate in real time, as well as the ability to type, draw, share images, chat or talk with collaborators, and even record work to review or submit to an instructor (Mallon & Bernsten, 2015). Students can use cloud-based document to collaborate and work in groups, rather than using emails with attachment of different versions of the same file. Some document creation tools such as Google Drive, Zoho, Etherpad, and Evernote, have features to encourage collaboration, such as built-in chat, colors for different authors, tracking changes, playback of writing, ability to insert comments, and different levels of sharing ranging from viewing to editing (Mallon & Bernsten, 2015). Online communication tools support synchronous communication such as online meetings, office hours, informal chats, guest speakers and webinars (Mallon & Bernsten, 2015). Such tools include Skype, Adobe Connect, Google Hangouts, Vyew, GoToMeeting, and MeetingBurner, with features including audio via webcam or phone, text chat, polling, drawing, and screen sharing.

Incorporating collaboration tools like the ones for online brainstorming (Padlet or MindMeister) into library instruction allows students to share their individual experiences and perspectives, leading to increased cognitive thinking and comprehension (Cooper, 2014). In addition, instructors use these tools to collect real-time analytics to monitor and assess the quality of students' online discussions (Krongard & McCormick, 2013). However, the anonymous participation provided by most of these tools can be abused by the students, or even lead to contributions unrelated to the topic (Mallon & Bernsten, 2015). With the availability of these tools, it is quite often taken for granted that technologies can enhance learning (Kirkwood & Price, 2014).

Computer Supported Collaborative Learning focuses on the use of computer technology to enhance collaborative interactions (Magnisalis et al., 2011). Research in CSCL deals with the possible use of technology in social and construction elements of collaborative learning (Nkambou et al., 2010). According to Kirkwood and Price (2014), computing technology can provide researchers with opportunities to use a variety of pedagogies, by exploiting its boundaries beyond the limits and paradigms currently in use.

The implementation of collaborative m-learning is still at its early stages, and need to be explored and expanded as mobile devices become more collaborative and affordable (Hamdan & Schaper, 2012). Laru (2012) agrees that future innovations will be towards mobile learning technologies, which must allow students to interact and collaborate in order to improve learning. One way to support collaborative learning is through the use of automated and artificially intelligent pedagogical approaches in mobile learning.

2.6.1 Computing Intelligence in Collaborative Learning

Technology has been used to support interactions which promote collaborative learning (Isik and Saygili, 2015). Kirkwood and Price (2014) identified three types of interventions which technology uses in learning, with relation to teaching activities: (1) replicating existing teaching practices, (2) supplementing existing teaching, and (3) transforming teaching and/or learning processes and outcomes. The third type of intervention aims to introduce learning facilitations into collaborative learning and subsequently transforming the learning process. Computing technology as a tool can support facilitative approaches, collaboration and interactions and, enquiry and integration (Dellit, 2001).

Computing technology, through web-based communication techniques, allow instructors and students to collaborate, communicate, share knowledge, and help each other to gain a better understanding of the learning content (Ataie et al., 2015). The social networking technologies (facebook, twitter, etc) have been used to help students network, collaborate, and share resources with one another for educational purposes (Ataie et al., 2015). Technology can spark learning activity and motivation through facilitation to improve student engagement (Anagnostopoulou et al., 2008) with several uses of technology being applied to engage students in distance learning (Ataie et al., 2015).

Computer support for collaborative learning becomes most effective when designed to foster productive social interactions (Deiglmayr & Rummel, 2015), such as mutual explanation, shared regulation, or argumentation (Dillenbourg et al., 2009). In order to identify such productive interactions, CSCL researchers typically analyze collaborative learning processes using automatically generated log files or from audio-video-recordings (Rummel et al., 2011). However, productive social interaction in CSCL remains unclear in terms of what it entails (Deiglmayr & Rummel, 2015). Computer technology in form of Internet and social networking applications provide support for collaboration in new ways that were not previously possible by expanding the opportunities for collaboration beyond the physical and practical limitations of a classroom (McLaren, 2014).

An intelligent tutoring system (ITS) targets the tutor towards the students' needs, by explicitly modeling but not comparing the students (Nkambou et al., 2010). In its simplest form, ITS can provide a sequence of hints in form of questions, while in more sophisticated form it could be a text-based dialog between one or more students and a computer agent (von Davier & Halpin, 2013). Most modern variations of ITS involve multiple users through computer-supported collaboration platforms (Hmelo-Silver et al., 2013). By allowing them to work together in ITS, the students act as a new source of explanations, hints, and answers to unresolved questions and misunderstandings. This compliments the domain-specific intelligence built into the system with the natural intelligence of group members. Additionally, a social component is introduced into collaborative learning through interactions which motivates students' engagement and knowledge retention (Bader-Natal, 2009). Computer Intelligence can support learner collaboration (Downes, 2012) as an essential and necessary aspect of effective learning. Researchers have explored approaches to develop artificial intelligence-based techniques and tools to support and guide collaboration (Adamson et al., 2014; McLaren et al., 2010).

The use of computer games is another approach for computer support in collaborative learning. In this setup, learners play within multiuser virtual environments engaging with each other, computer agents, and the simulated environment (Metcalf et al., 2011). Multiuser video games provide collaborative learning activities (Villalta et al., 2011) which engage learners in group activities.

2.6.2 Intelligent Agents and Collaborative Learning

Udanor (2011) defines a computer agent as a computer software component which behaves as a human agent by working on behalf of a client. An agent functions continuously and autonomously within a certain environment and carries out its activities in a flexible and intelligent way in response to those changes in environment (Bradshaw, 1997). Agents are also interactive or communicative (they can send and receive messages with other agents), exist in some environment that they can sense and act upon that environment), and exhibit other properties such as adaptability, reactivity, proactivity, mobility, responsivity and rationality. An agent can perform one or more tasks in its area of implementation so as to achieve a goal (Outtagarts, 2009). Distributed Artificial Intelligence (DAI) is an area in Artificial Intelligence

(AI) where intelligent agents are used in developing information systems, especially Decision Support Systems (DSS) (Adla et al., 2012).

Computer agents are classified depending on their type, implementation technology, or by their application domain (Erlin et al., 2008). Nwana (1996) classified agents into seven categories as indicated in Figure 2-6: (1) collaborative agent negotiate in order to reach mutually acceptable agreements on some matters, general characteristics of these agents include autonomy, social ability, responsiveness and proactiveness; (2) interface agent is a personal assistant who collaborates with the user in the same work environment; (3) mobile agent has the ability to move around some network; (4) information and internet agent manages, manipulates or collates information from many distributed sources; essentially, it helps manage the vast amount of information; (5) reactive agent shows a reaction or response to the user, and does not wait to be told what to do next; (6) hybrid agent is one whose constitution is a combination of two or more agent philosophies within a singular agent; and (7) heterogeneous agent system contain one or more hybrid agents which belong to two or more different agent classes.

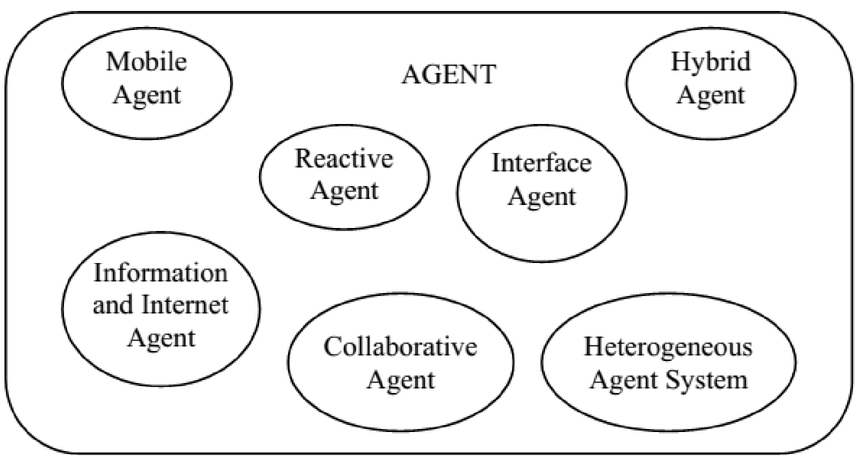


Figure 2-6: Classification of Agents
(Source: Erlin et al., 2008)

Yee-King et al. (2014) defined three types of agents used in learning environments: pedagogical agents, peer learning agents and demonstrating agents. Intelligent Pedagogical Agents (IPA) assist learners by providing pedagogical guidance, tutorials, the ability to find learning resources, tracking learners' progress, aid collaborative and communicating learning functions (Soliman & Guetl, 2010a), creating and providing adaptive dialogues, give guidance, resolve difficulties and motivate learners (Soliman & Guetl, 2010b). Soliman (2013) is of the idea that IPAs should take more of a mediation role to facilitate dialogue and group interaction in collaborative learning. There are two subcategories of IPAs: conversational agents and teachable agents. While conversational agents hold and facilitate conversations with learners, teachable agents are taught by the students in order to perform some assigned tasks like solving puzzles (Veletsianos & Russell, 2013). The conversational agents used in collaborative environments range from simple chat interfaces to full virtual talking heads with full expressiveness. Chat interfaces are enhanced using menus, and interactive simulations which allow cursor movements within a shared workspace, provide a wide range of conversational contexts and collaborative interaction (OECD, 2013). With conversational agents, students are provided with conceptual support (Dyke at. al, 2014). Conversational agents are known for providing dynamic support for collaborative learning and consequently improve the learning outcomes (Kumar and Rosé, 2010).

According to Wooldridge and Jennings (1995), agents have been conveniently used in collaborative learning, maybe due to their characteristics which match those of students in collaborative learning. Due to their features, computer agents are suitable for collaborative learning to provide control over interaction and assessment for group members within short time constraints (Looi, 2014). Intelligent autonomous agents can be built into teams to solve the problems collaboratively, with functionalities and skills already distributed among the agents (Aydin, 2012). Agents have also been designed and used in collaborative learning to play different roles: tutor, facilitator, monitoring, assessment and information, and they can facilitate collaboration processes such as coordination, teacher intervention and group interaction (Erlin et al., 2008). Intelligent agents are good for incorporating learning theories into collaborative interactions and environments (Miao et al., 2010). The advantage of using agents is that they adapt to the learning experience in order to meet the learner's requirements or to meet the changes in the learning environment (Henry & Sankaranarayanan, 2010).

Intelligent agents are preferred due to their high degree of self-determination capabilities, and their capability to decide for themselves when, where, and under what condition to perform their actions (Adla et al., 2012). Various researchers in education have used agents to provide learning support. Kutay and Ho (2004) used rule-based agents to motivate and guide learners in generating concepts from a course, elaborating the concepts and differentiating them as a way on analyzing their learning and interactions. Magnus et al. (2010) used a conversational agent to guide a conversation by focusing on a topic by use of multiple choice questions. Agents and learners can also engage in augmented learning as used by Tao et al. (2009) on topic of food chains. Spoelstra and Sklar (2007) also used an agent to simulate interactions between learners within a group. Ahdon (2013) designed an agent on a one-to-one tutoring environment where the agent performed some key pedagogical functions like student monitoring and feedback, probing questions, hints and explanation. Intelligent Pedagogical Agents (IPA) have been used to assist learners by creating and providing adaptive dialogues, give guidance, resolve difficulties and motivate learners (Soliman & Guetl, 2010b). Computer agents in form of avatars have also been used to simulate collaboration, adding flexibility and control than with real human collaboration (OECD, 2013).

Agents are also known to reside in environments containing other agents, referred to as Multiagent Systems (MAS) (Bordini et al., 2001). In MAS, a set of proactive agents act individually to solve problems collectively (Ayhan, 2013). These agents must use a certain level of coordination which allows each individual agent to proactively and efficiently collaborate in solving the problems using individual intelligence (Aydin, 2012). The use of MAS in education provides some benefits, such as, (i) collaborative - provides intelligent interaction among the collaborative team members, (ii) adaptive - provides the personification of students and tutors and saved all users information from the routine operations, (iii) student-teacher interaction - provides a better interactivity among the students and teacher, (iv) intelligent - gives intelligence to the e-learning system so that the system can know about its users and help them accordingly, and (v) allow reusability - remove duplication of effort- jobs can be shared among different applications of the system. Agents in MAS intelligently interact with each other to support the learning processes (Arif & Hussain, 2015). Social machines are new technological systems from MAS community which allow human and computer agents to socially interact, sometimes to achieve common goals (Yee-King et. al, 2014). Social machines consist of many rational agents, each of which can model other agents in the system, and that can interact to achieve shared or individual goals.

Multi-agent systems which offer various services in e-learning systems use agents which are customized to the needs of both the tutors and the students. Student agents assist in searching for educational and monitoring the students' progress while teacher agents assist teachers to dispense learning resources to the students and observing their progress. Figure 2-7 shows how different agents play various roles towards working together to achieve a complex goal (Jelonek, 2015).

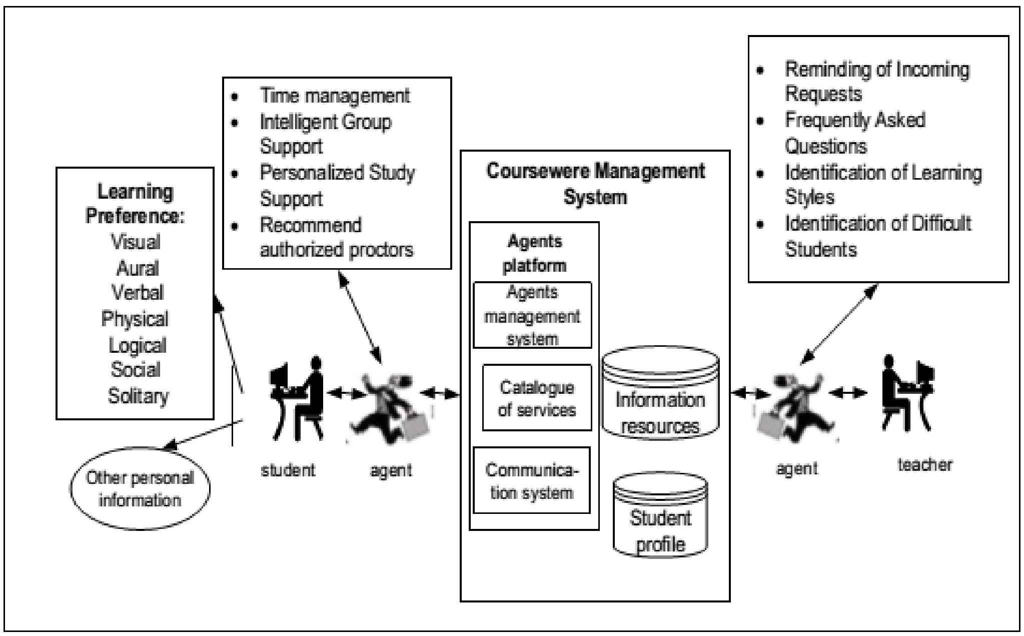


Figure 2-7: An Intelligent Multi-Agent System for E-Learning System

Source: Jelonek (2015)

This multi-agent system consists of an agents' management system and a communication channel amongst the agents used for exchanging information.

Major Issue with Intelligent Agents

The use of intelligent agents in collaborative learning has its own challenges. In his experiment on use of software agents to scaffold and guide group cognition, Stahl (2013) noted that while collaboration involves following the lead of the students (individually and as a group), software agents are not good at understanding student thinking. The software agents were sometimes distracting, confusing, and disruptive. By not being co-present to attend the shared object of attention like in human way, software agents use generic algorithms designed outside the context of current interaction (Stahl, 2013). However, an intelligent agent in an Intelligent Collaborative Learning System (ICLS) can play the role of a group facilitator by analyzing the group's interactions based on students' communication patterns and determine how and when to support collaboration. Such an agent dynamically analyses the group conversation and actions to come up with strategies and methods for improving the learning process (Soller, 2001).

According to Soller et al.(2004), the roles of agents in collaborative learning can be summarized as follows: (1) monitoring the collaborative learning process; (2) providing feedback and guidance to activate interaction and collaboration; (3) giving information on the current state of a learner's interaction in the collaborative learning process; and (4) giving advice on the learning process according to the process and strategy of collaborative learning by comparing the current and ideal states. In line with Conati and Klawe (2002), the artificial agents oversee the collaboration process and detects when the conditions for effective collaboration are met or not, and motivates the collaboration.

2.6.3 Intelligent Agent Architectures

Multiple agents may exist in the same environment as happens in complex systems. The study of systems made of multiple heterogeneous agents is called a multi-agent system – MAS (Shoham & Leyton-Brown, 2008). Agents in MAS may have a common or conflicting goal to achieve (Yu et al., 2010). Agents with a common goal cooperate in order to accomplish their goal (Pozna et al., 2011), while agents with contradictory goals compete with each other (Leyton-Brown, 2003). Agents which cooperate are required to reason about when and what to do when interacting.

Agent architecture is an essential consideration in building an agent-based system. It is like a brain of an agent in reasoning and decision making when solving problem and achieving goals (Chin et al., 2014). Agent architecture contains techniques and algorithms on how to support the agents and how they interact (Maes, 1991). Some common agent architectures include logic-based architecture, BDI architecture, reactive architecture, hybrid architecture, cognitive architecture, and semantic architecture. The architectures are discussed below:

a. Logic-Based Architecture

This architecture is also known as symbolic-based or deliberative and uses symbolic representation for reasoning (Newell & Simon, 1976). It models and represents the agent behavior and the environment using symbolic representation. The specification of the agent indicates how the agent behaves, how goals are generated and the action the agent can take (Chin et al., 2014). In the implementation, the inference rules are encoded to enable the agent to decide what to do (Russell & Norvig, 1995).

Even though the architecture is simple, it has some problems. First, it is difficult to model the environment using symbolic representation accurately. Secondly, it is difficult to represent information in symbolic form suitable enough for the agents to reason in a restricted environment. Lastly, the conversion of input from the percepts may not be precise enough to describe the environment. It becomes very difficult to implement all the rules for a situation that agent will encounter since the deduction process is based on set of inference rules (Chin et al., 2014).

b. Reactive Architecture

This architecture directly maps a situation into an action. The agents respond to changes in the environment in a stimulus-response based approach. The architecture is implemented using a set of sensors and effectors, where an input is mapped to the effectors. The most common reactive architecture is Brook's subsumption architecture (Brooks, 1986). Figure 2-8 illustrates an example of reactive architecture, where each of the percept situations is mapped into an action which specifically responds to the percept situation.

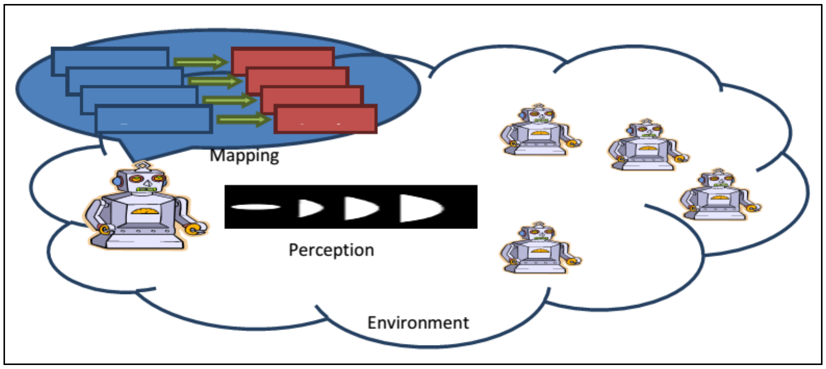


Figure 2-8: An example of Reactive Architecture

Source: Chin et al. (2014)

c. BDI Architecture

BDI architecture is a deliberative agent architecture based on mental states characteristic such as belief, desire, and intention. It reaches its conclusions through the use of beliefs and knowledge. The agents in BDI architecture consists of three logic components: beliefs, desires and intentions. Beliefs consist of information that the agent has about the world. The desires of the agent motivate the possible options for the agent to carry out the actions. The intentions are the agent's commitments towards its desires and beliefs, and are a key component in practical reasoning (Chin et al., 2014).

The design of BDI architecture is clear in the functional decomposition of the agent subsystem making the formal logic properties easy to study. However, the efficient implementation of the functionality in subsystem is not clear. Thus, the agents are required to balance between commitment (Rao & Georgeff, 1991) and reconsideration (Wooldridge & Parsons, 1998). Reconsidering makes the agent not to try to achieve an intention which is not achievable or no longer valid. Again, too much reconsideration might make the agent not to achieve intentions due to insufficient time working on the task.

d. Layered (Hybrid) Architecture

This architecture is a hybrid of reactive and deliberative agent architecture. It combines both the advantages of logic-based and reactive architecture and alleviates the problems in both architectures. Different behaviors are dealt with as hierarchical layers in subsystems (Chin et al., 2014). Horizontal and vertical interactions are possible. In the horizontal architecture, each layer directly connects to the sensory input and action output. Thus, each layer behaves like an agent mapping an input to the action to be performed (see Figure 2-9).

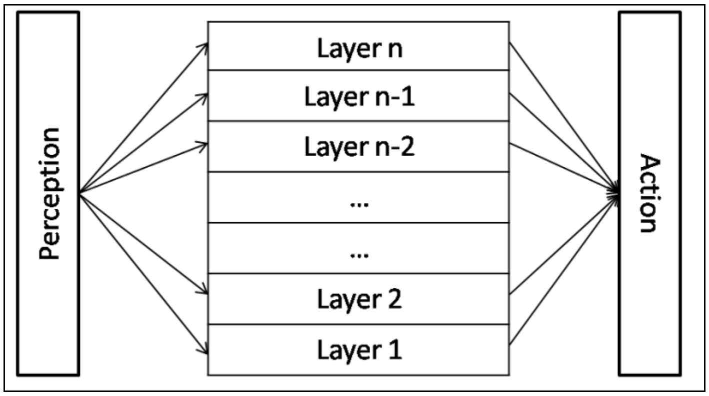


Figure 2-9: Horizontal Layer Architecture

Source: Chin et al. (2014)

Only *n* layers are required to map *n* different behaviors in horizontal layer architecture. However, the inconsistent actions between layer interactions require a mediator function. Another challenge is the enormous number of possible interactions between horizontal layers - m^n (where m is the number of actions per layer).

Vertical layer architecture gives a solution to these problems by having the sensory input and action output each dealt with by at most one layer each. In a vertical architecture, the control flows from the first layer that gets data from sensors to the last layer that generates action output (see Figure 2-10).

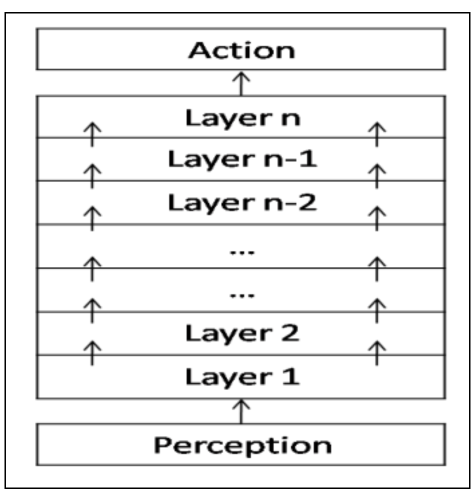


Figure 2-10: Vertical Layer Architecture

Source: Chin et al. (2014)

e. Cognitive Architecture

This architecture uses cognitive sciences which focus on the human cognition and psychology. Cognitive architecture began with a specific class of architecture known as production systems (Neches et al., 1987) and evolved over time. The cognitive architecture is different from multi-agent approach in the following ways (Langley et al., 2009):

- cognitive architecture comes with a programming formalism to encode knowledge and associates it with its interpreter,
- it has strong assumptions on the representation of knowledge and the processes that operate on them,
- it assumes a modular representation of knowledge,
- it offers intelligent behavior at the systems level, rather than at the level of component methods designed for specialized tasks, and
- it provides a unified approach in which a common set of representations and mechanisms reduces the need for such careful crafting.

Summary of Literature Review

Learning becomes more effective when it becomes a group's joint effort and when treated as a social activity (Domalewska, 2014). Collaborative learning can be summarized using three main components (1) construction of learners understanding rather than its transmission; (2) social interaction facilitates learning; and (3) realistic learning tasks promote meaningful collaborative learning. The biggest challenge is the implementation of collaboration in the learning process, that is, effective implementation of collaborative learning (Wicaksono, 2013).

M-learning is still immature in area of pedagogy (Park, 2011) and use mobile devices for collaborative learning is less explored (DeWitt et al., 2014). Most mobile learning systems do not provide support for the collaborative learning processes (Wu et al., 2012) and only a few of them have explicitly addressed the problem of mobile devices in the foreground of interaction (Eliasson, 2012). These challenges in collaborative m-learning can only be understood and tackled in the context of collaborative learning process.

The collaborative learning process should allow learners to grow their interest and promote the sharing of ideas with each other (Karatas & Baki, 2013). The two learning theories discussed in the literature review, that is, social constructivism theory and social cognitive theory, give a sound understanding of collaborative learning and how knowledge is created. According to social constructivism, knowledge is developed when learners interact and collaborate with each other (Vygotsky, 1978). In collaborative learning, a learner constructs sharable artifacts (Girvan et al., 2013), with dialogue and argument used as valuable learning opportunities (Biggs & Tang, 2011). Thus, collaborative learning is viewed as a social process of knowledge building (Said et. al, 2015). In social cognitive theory, knowledge construction takes place when group members engage in learning activities, receive feedback and participate in group interactions, with cognition being a group process with learning and knowledge being shaped by the interactions (Bandura, 2001). Thus, social cognitive theory advocates for an active learning environment where students get highly engaged through social interactions (Schunk, 2012).

Learning cannot take place in collaborative environment in the absence of social interactions, that is, where group members do not question, analyze, synthesize, evaluate, and make decisions (Deloach & Greenlaw, 2005). Most research on collaborative learning has been done using quantitative results to measure the success of collaboration or its failure (Cerny & Mannova, 2011) but with little emphasis on social interactions amongst members (Yee-King et. al, 2014). According to Järvelä (2014), there is not enough research about how group members engage, sustain and productively regulate collaborative processes. In order to understand how groups construct knowledge the study of group interactions among participants is important (Stahl, 2011a).

Students mutually create knowledge through collaborative learning (Cooper & Cowie, 2010) using many ways such as questioning, clarifying or giving support (Mansor & Rahim, 2009). Knowledge co-construction involves high-level interactive processes where understanding and ideas are emphasized, as opposed to information sharing where different pieces of information are pooled together (Näykki, 2014). Students reach high-level knowledge construction when they get involved in arguments, justification, or decision making transforming them into critical thinkers (McLoughlin & Luca, 2000). Thus, there is need for the participants who jointly construct knowledge to be aware of the group processes in order to gain from the collaboration (Blake & Scanlon, 2012). Thus, there is need to shift focus from the product of collaboration to the process of collaborative learning.

The literature review identifies three important factors whose presence is important for effective interactions: presence of a controversial task, participation in group activities and regulating group cognitive conflicts. Meaningful learning takes place effectively when group members engage in a controversial issue (Ractham & Kaewkitipong, 2012). Tasks which are trivial, obvious and unambiguous do not provide opportunities for group negotiation because there is little or nothing to disagree about (Dillenbourg, 1999). An effective collaborative task is one that enables all participants to express themselves and make significant contributions (Rimor et al., 2010). Successful collaboration acknowledges that everyone has ideas to contribute in the collaborative learning (CORP/U, 2013). Lack of active participation and interaction by learners make them lose motivation and feel less satisfied (Park & Choi, 2009). Participation needs to be encouraged for group learning to take place. Cognitive conflicts arise when the incongruities exist between the learner’s (individual) knowledge and the collective knowledge in the artifact (Moskaliuk et al., 2012). The cognitive conflicts are critical in triggering knowledge creation and are facilitated through social interactions, leading to higher levels of learning (Lai, 2011). These conflicts motivate the learners to explore, combine and refine each other’s ideas and understandings, and they assist the learner in identifying, challenging and reconstructing likely misconceptions (Aarnio, 2015). It is important to tackle those conflicts as a creative source of knowledge construction for collaboration to be realized (Garmston & Zimmerman, 2013).

Facilitation of group interactions in collaborative learning results to better and effective learning (Kim et al., 2014). Song and McNary (2011) admit the need to facilitate the learning experience through quality learner interaction and engagement. There exist strategies to facilitate group participation and regulate group cognitive conflicts. Two of the strategies for facilitating group participation include (i) Turn taking, which is an organized, co-ordinated activity to allows turn allocation techniques for selecting the next contributor (Sidnell, 2010) to ensure that some members do not over-contribute while other under-contribute (OECD, 2013), and (ii) Informative feedback to promote learner engagement (Liu et al., 2015) by providing positive reinforcement or constructive suggestions that help in the collaborative learning (Cooper, 2014). Group cognitive conflicts can be regulated through: (i) Role playing which allows group members assume different responsibilities which encourage them to look at the group problem from different perspectives, and (ii) Guided negotiations where the use of interaction rules help in regulating a discussion (Hamdan & Schaper, 2012).

Computer intelligence in Intelligent Tutoring Systems (ITS) can provide a sequence of hints in form of questions, while in more sophisticated form it could be a text-based dialog between one or more students and a computer agent (von Davier & Halpin, 2013). Computer agents have been used in collaborative learning to provide control over interaction and assessment for group members within short time constraints (Looi, 2014). Intelligent agents in Multi-Agent Systems (MAS) have been used in collaborative learning. Such agents are capable of negotiating and resolving conflicts, but only need some enhanced functionality in terms of addition of pedagogical functions (Soliman & Guetl, 2010a).

The future innovations will be towards mobile learning technologies, which must allow students to interact and collaborate in order to improve learning (Laru, 2012). Such a solution can be provided by intelligent agents.

2.7 Conceptual Framework

A number of constructs were adopted in the study to guide the research methodology and the design of the mobile learning environment. The constructs were based on the literature review. These constructs were guided by group interactions in collaborative mobile learning and online collaborative learning. The constructs were also guided by the types of supports used in facilitating social interactions. The constructs and their relationships are indicated in the conceptual framework in Figure 2-11.

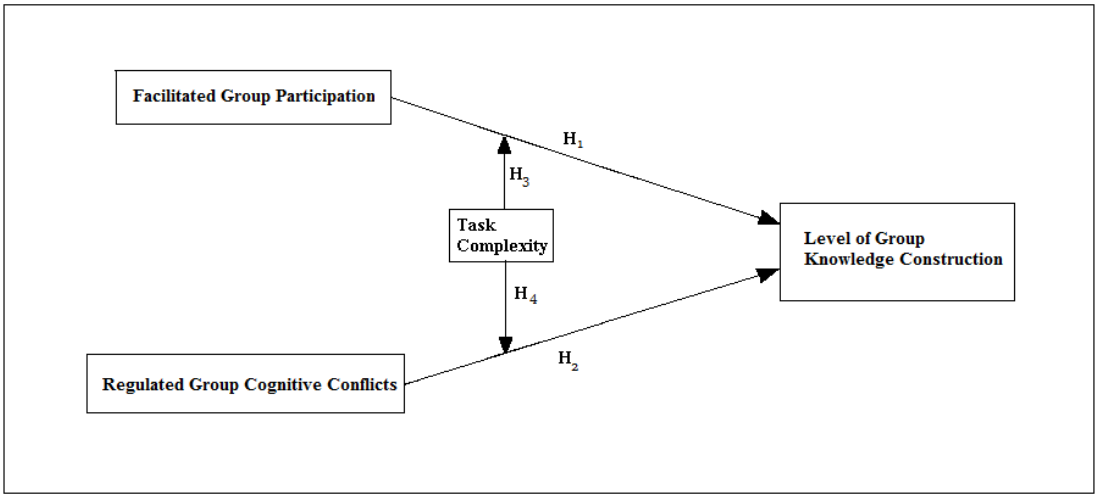


Figure 2-11: Conceptual Framework

(Source: Author)

2.7.1 Variables

Dependent variables

The research study has one dependent variable *Level of Group Knowledge Construction*. This is an outcome of collaborative learning.

Independent variables

There are two independent variables: *Facilitated Group Participation* and *Regulated Group Cognitive Conflicts*. The independent variable *Facilitated Group Participation* has three possible values {turn-taking, informative feedback, and no facilitated participation}. The independent variable *Regulated Group Cognitive Conflicts* has three possible values {role playing, guided negotiation, and no regulated group cognitive conflict}.

Moderator Variable

The only moderator variable used in this research study is *Task Complexity*. It is expected to have moderating effects on the relationships between the independent and dependent variables.

2.7.2 Hypotheses

The alternate hypotheses are used in this study. There are four (4) hypotheses: two direct path hypotheses and two moderator hypotheses. Hypotheses 1 and 2 have two sub-hypotheses each.

H_1 - The use of facilitated group participation positively affects the level of group knowledge construction

H_{1a} - The use of informative feedback positively affects the level of group knowledge construction

H_{1b} - The use of turn taking positively affects the level of group knowledge construction

H_2 - The use of regulated group cognitive conflict positively affects the level of group knowledge construction

H_{2a} - The use of role playing positively affects the level of group knowledge construction

H_{2b} - The use of guided negotiation positively affects the level of group knowledge construction

H_3 - Task complexity moderates the relationship between facilitated group participation and the level of group knowledge construction.

H_4 - Task complexity moderates the relationship between regulated group cognitive conflicts and the level of group knowledge construction.

Chapter 3: Methodology – System Development

3.0 Introduction

This chapter helps to answer research question 1 of the study which asks:

> *Can a mobile application be designed, developed and implemented for facilitating group interactions using intelligent agents?*

A solution in form of a collaborative m-learning prototype to facilitate group interactions is proposed in this research study. The prototype uses the four agents to match the four facilitations identified in the literature review.

The chapter discusses how collaborative mobile application was designed, developed, tested implementation and validated. The chapter consists of a development methodology for mobile applications (Section 3.1), the design of the mobile application using facilitated group participation and regulated group cognitive conflicts within an architecture (Section 3.2), development and implementation of the mobile prototype (Section 3.3), and testing and validation of the application (section 3.4).

3.1 Mobile Application Development Methodology

3.1.0 Introduction

Mobile Application Development involves developing applications for small low-power handheld devices which are either pre-installed on phones during manufacture, or downloaded by customers from app stores and other mobile software distribution platforms (Flora & Chande, 2013). Developing mobile applications has its own challenges like: integrating software with hardware, limited storage, reliability and performance (Agarwal & Wasserman, 2010), limited battery life, limited display size (Eom & Lee, 2013). Other challenges include wireless features such as bandwidth variability and intermittent connections (Kaleel & HariShankar, 2013), transmission signal stability and satisfying changing requirements which pose a challenge in developing mobile applications (Eom & Lee, 2013).

Various mobile development methodologies exist which deal with the above challenges but on different capacities. The different methodologies involve different steps and activities which vary from one development methodology to another. However, most of them include planning, requirement, analysis, design and implementation (Jamwal, 2010). According to Sommerville (2006), there is need to have a distinct mobile application development lifecycle driven by various complex functionality and services like telephony services, location based services and different connectivity modes. This study used a development methodology called Mobile Application Development Lifecycle (MADLC) which is discussed below.

3.1.1 Mobile Application Development Lifecycle (MADLC)

Vithani and Kumar (2014) proposed a framework lifecycle for mobile application called the Mobile Application Development Lifecycle (MADLC). The lifecycle consists of the following phases: Identification, Design, Development, Prototyping, Testing and Maintenance. This lifecycle has been used in developing Android mobile applications, and deals with characteristics of mobile applications such as life span, complex functionalities, fewer physical interfaces, more number of screens for interaction, battery and memory usage, cross platform development and maintenance.

In Identification Phase new ideas or improvements to the current application are collected and classified. These ideas can come from customers or generated by developers through brainstorming. They are then filtered and discussed by the mobile application idea team made of the business and IT representatives. The time required to develop the application is also considered in this phase. The work in this phase is documented and forwarded to the design team. The Design Phase develops the idea from the mobile application team into an initial design of the application. The target mobile platform is identified and a decision is made whether the application will be a free or trial version with minimum features or released as a premium version. The application is broken down into modules and into combination of modules which are to be released in the prototype fashion. The functional requirements and the software architecture of the application are developed. The user interface is designed to determine the flow of the application and is done using a storyboard. The documented work is used by the development team for coding. The application is coded in the Development Phase.

Development process can be divided into Coding for Functional Requirement and Coding for User Interface requirements. Different modules can be coded simultaneously and then integrated later. The user interface should support as many mobile operating system platforms as possible. The documentation of the development phase is then forwarded to the prototyping phase. In the Prototyping Phase, the functional requirements of each prototype are analyzed; the prototypes are tested and sent to the client for feedback. Any changes are implemented through the development phase after feedback is received from the client. The prototype is then integrated with others, tested and sent to the client. According to Sommerville (2006), the development, prototyping and testing phases are repeated until the final prototype is ready. The final prototype is sent to the client for a final feedback. The work done in this prototyping phase is documented and then forwarded to the testing phase. In the Testing Phase, the prototype is tested on an emulator/simulator followed by testing on the real device. The emulator/simulator is often provided in the SDK. Testing on the real device should be done on multiple operating system versions and multiple models of handsets with various screen size. The test cases are documented and forwarded to the client for feedback. Deployment Phase involves uploading the application to the mobile devices for use. This is done after testing is completed and the final feedback obtained from the client. The deployable application is done using a particular file format required on operating system platform. Maintenance Phase allows for collection of feedback from users and required changes made by fixing bugs or making improvements. Performances improvements, additional functionality, new user interfaces and security patches should be provided at regular intervals in the form of updates to the application.

3.2 Design of the Mobile Prototype

3.2.0 Introduction

Application design is a primary consideration before initiating the development process, irrespective whether a framework is used or not (MADDT, 2013). This section discusses the various design approaches used for this mobile prototype

3.2.1 Designing Facilitations

Proper design of interaction within the learning environment can significantly improve student achievement (Mahle, 2011). Domun & Badadur (2014) emphasize the need to design opportunities for collaboration and interaction. Two types of facilitations were designed with systems architecture used in the implementation of the mobile prototype. They include facilitated participation and regulated cognitive conflicts.

a. Facilitated Group Participation

The aim of facilitating group participation was to ensure all members in a discussion group got almost equal opportunity to contribute to the group knowledge construction. Two strategies used to facilitate group participation in this study are turn-taking and informative feedback.

Turn taking provided equal opportunities to students to make them develop a sense of ownership of the newly constructed knowledge (Jonassen, 2000). A round-robin strategy was adopted where each member was provided with a chance to contribute equally in each of the stages of group problem solving. Thus, no member can contribute to the group discussion twice before the others members in the same group have contributed. This makes the group members move together in unison in every stage in problem solving. Turn taking was meant to ensure that each member made a contribution to the discussion by having their ideas heard through providing information, questions or answers before any other member contributed again (Skantze et al., 2014). Also, turn taking was meant to 'coerce' a member to contribute to the discussion since the chance to contribute was always available for each member. That way, turn taking ensured active participation by allowing students to contribute at appropriate times (Soller, 2001)**.**

The type of informative feedback for facilitating group participation used in this mobile prototype is referred to as "participatory feedback" was meant to monitor student dormancy or dominance in the discussion. When a student became dormant, an alert was sent to remind him or her of the need to continue participating in the discussion. When a student over-contributed, an alert to let him or her allow others to contribute was sent.

b. Design for Regulated Group Cognitive Conflicts

Regulation of cognitive conflicts was meant to ensure that the group members reached high levels of group knowledge construction through proper balancing of the agreements and disagreements which occurred during group problem solving. The two types of facilitations used for regulating group cognitive conflicts were role playing and guided negotiation.

The m-learning prototype used three different roles adopted from Vonderwell and Zachariah (2005) for three participants in a discussion group: starter, responder and supporter or critic. A starter questioned, raised issues and reflected on learning material and content. A responder answered questions and posted new questions. A supporter tried to justify the claim and elaborated it, while a critic challenged the original claim and identified weaknesses. These roles were to be taken by any member in the group and also rotated amongst group members to allow different responsibilities for different members for provision of different opportunities. For example, a role of a starter allowed a member to initiate a discussion, and also contribute later as a supporter.

Guided negotiations for managing cognitive conflicts involved regulating the level of agreements/disagreements within the discussion group. The group members were provided with sentence guides as a way of structuring the discussion (Scheuer et al, 2013) and to improve the quality of their discussion. The sentences were listed under key heading namely 'Propose/Counter-Propose', 'Agree/Disagree', 'Question/Answer' and 'Providing Information'. Each of the key sentences was provided with an option of an explanation or elaboration. For example, a sentence guide allowed a member to select to answer a question followed by an explanation of the same.

The four facilitations (turn taking, informative feedback, role playing and guided negotiation) were incorporated in the overall system architecture which is discussed in the next section.

3.2.2 Collaborative M-learning Agent-Based Architecture (CMABA)

The Agent architecture used in this prototype brought together a number of software modules implemented using intelligent agents according to the theory of agent (Adla et al., 2012). Agnts were chosen because they can play the role of a group facilitator by analyzing the group's interactions based on students' communication patterns and determine how and when to support collaboration. Such agents dynamically analyze the group conversation and actions to come up with strategies and methods for improving the learning process (Soller, 2001). The reactive, pro-active, and social features of agents were used in the architecture. First, the agents responded to changes in the collaborative learning environment such as providing feedback to learners when requested to. Secondly, they took initiatives by prompting learners to participate in online discussions when they are dormant. Finally, the agents communicated with each other through the data that they generate and use in facilitating the interactions.

A mobile-based agent architecture called Collaborative M-learning Agent-Based Architecture (CMABA) was developed (Figure 3-1). This was due to lack of a framework and methodological approach of using agents in collaborative learning (Adla et al., 2012). CMABA which has four layers: User Layer, Mobile Platform Layer, System Layer and Database Layer. The User Layer is used for communicating between the application users and the system through online discussion forums. The Mobile Platform Layer is made of the mobile phone interfaces which allow the students to interact and access the system. It caters for the support of different types of phones available to the students. The System Layer is the core of this architecture and consists of the four Intelligent Agents which run on top of the Moodle Learning Management system platform. The Database Layer allows for the storage and access of data pertaining to the systems, such as the discussion forum messages posted by students, etc.

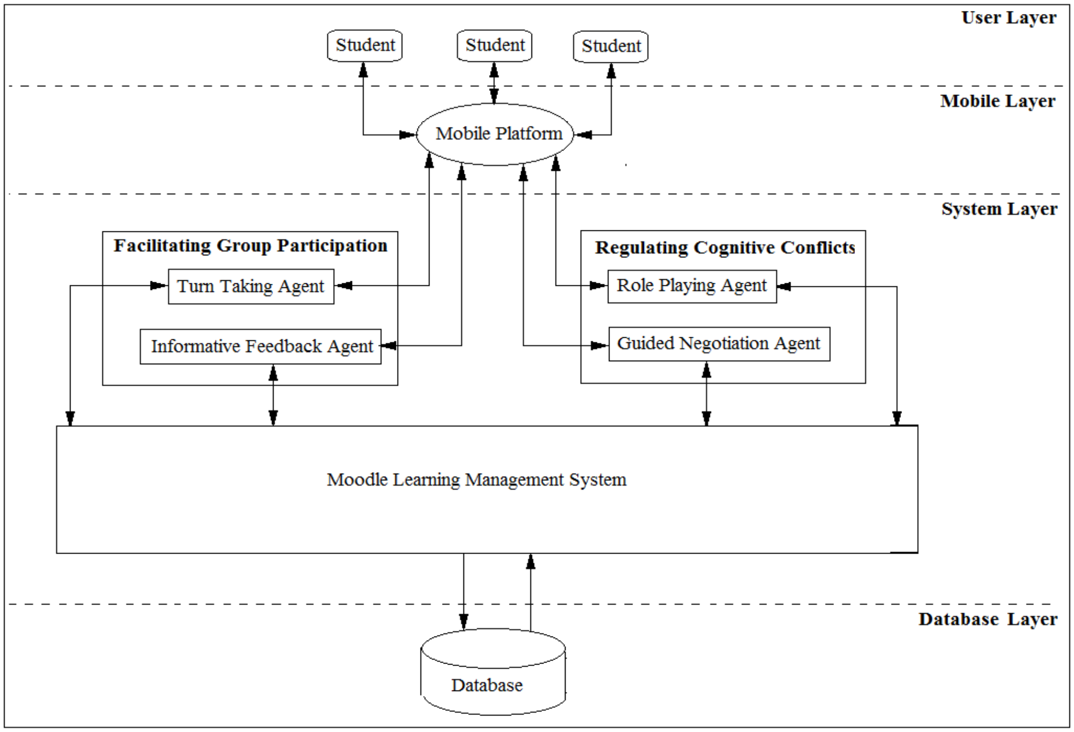


Figure 3-1: Collaborative m-learning Agent-based Architecture (CMABA)

Each agent in the System Layer implements one of the four facilitations discussed above, that is, turn taking, informative feedback, role-playing and guided negotiation. This research used automatic analysis of collaboration to detect when an agent should intervene (Cui et al., 2009). Specifically, the agents collected information, analyzed it and generated alternatives that allowed the user to focus on the effort to solve the group problem. The intelligent agents aimed to provide automated and intelligent pedagogical support while improving engagement throughout collaboration (Soliman, 2013).

The two agents used for facilitating group participation are turn-taking agent and informative feedback agent, while the two for regulating group cognitive conflicts are role playing agent and guided negotiation agent. The agents within the System Layer are discussed in details below.

a. Turn Taking agent

This agent regulated the members' contributions in a discussion by allocating each member a time slot in a round robin approach. This implied that a member could not contribute twice before another member from the same group contributed to the discussion. The algorithm used by this agent is shown in Figure 3-2.

1. *The agent notes each member who has contributed in the discussion forum*
2. *If a member contributes again before another member in the group has contributed, then*
   This member is prompted to wait for contributions from other members
   Else
   The members is allowed to contribute

Figure 3-2: Algorithm for Turn Taking agent

b. Informative Feedback agent

The need for instructors to monitor discussions and postings for provision of informative feedback poses a great challenge (Nandi et. al, 2012). The informative feedback agent monitored the participation of each member in the group discussion. The agent calculated the participation statistics based on percentage contribution by each member of the group. The passive (dormant) members were prompted to contribute through reminders and asking their opinions in the course of the discussion. The dominant members were requested to provide chances to other members. The algorithm used by the Informative Feedback agent is shown in Figure 3-3.

1. *Collect memberIds for the last six contributions made by group members*
2. *Calculate contributions made by each member from those last 6 contributions.*
3. *If memberContribution > 4 (5 or 6) then*
   Member is prompted to wait for contributions from other member
   ElseIf a member has made > 2 and < 5 contributions (3 or 4) then
   No prompt is provided
   ElseIf a member has made < 2 (0 or 1) then
   Members is requested to contribute to the discussion

Figure 3-3: Algorithm for Informative Feedback agent

On average, if three members in a discussion group were to make two contributions each, that would amount to six contributions. Six contributions would be too many for a group when made by only some members, and especially by only one member. Thus six was used as the threshold value. On the other hand, an average of one contribution per person by three members would amount to three contributions. That seemed a reasonable (average) contribution by a person out of six contributions. However, zero or one contribution was an under-contribution. Thus, four or five contributions out of six were referred to as many, three or four as average, and zero or one as tool few.

c. Role playing agent

This agent regulated the group cognitive conflict by encouraging members to choose a role to play during the group discussions. Each role had a specific set of task associated with it, and this controlled the way the discussion was conducted. Different roles were provided with different set of tasks which determined the way a discussion took place. The agent also dynamically gave the current role played by each group member to the others. For example, a member could initiate a discussion (starter role) and later support a member's contribution (supporter role) as the discussion continues. The algorithm for the role playing agent is shown in Figure 3-4.

1. *Identify the current role played by each group members from the contributions*
2. *Display the different roles played by the all group members in the discussion forum and their specific duties*
3. *Suggests possible roles and allows for role selection during the discussion.*
4. *Allow and facilitate swapping of roles by the participants themselves every time they participate in the discussion.*
5. *If member selects different role*
   Display update to show current role and associated responsibilities

Figure 3-4: Algorithm for Role Playing agent

d. Guided Negotiation agent

The Guided Negotiation agent assisted the students by providing them with sentence openers to allow them to choose the type of contribution they wanted to make. The sentence openers used were Propose, Counter-Propose, Agree/Disagree, Question, Answer and Provide Information. The student selected the sentence opener and then made the contribution to the discussion based on that selection. This agent also provided the students with an option to elaborate or explain their contributions. The algorithm for this agent is displayed in Figure 3-5.

1. The agent provides a group member with a set of sentence guides and elaboration options to choose from
2. The group member chooses the sentence guide matching the type of contribution to make
3. The agent checks whether the contribution made by member matches the sentence guide
4. If match then
Contribution accepted
Else
Member given another chance to contribute
5. If the member wishes to elaborate or explain the contribution
Member selects the option to elaborate/explanation and types an elaboration/explanation

Figure 3-5: Algorithm for Guided Negotiation agent

The Guided Negotiation agent used a different interface from the other agents to allow for leaners to select the type of contribution to make and/or whether to explain or elaborate. The mobile interface for this agent is shown in Figure 3-6.

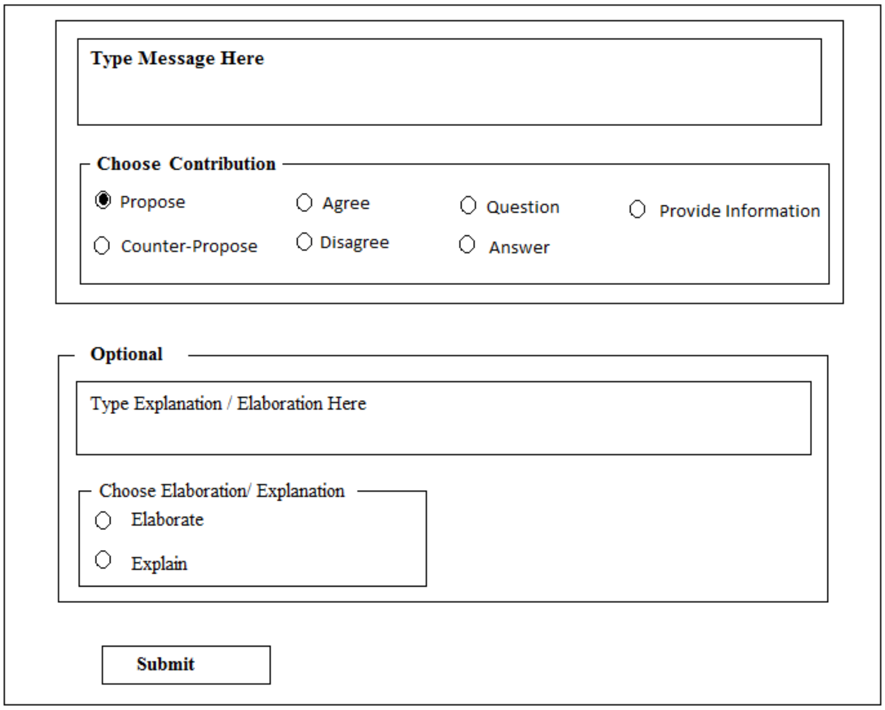


Figure 3-6: Mobile Interface for the Guided Negotiation facilitation

The aim of this facilitation was to encourage learners to elaborate and justify their reasoning.

3.3.3 Database Design

A database design was used to develop the database for the storage of the data for the system. Other than storing the data about the courses offered to students and their details, the system also stored data about the discussions and the messages posted during the discussions. The Entity Relationship Diagram (ERD) of the database is shown in Figure 3-7.

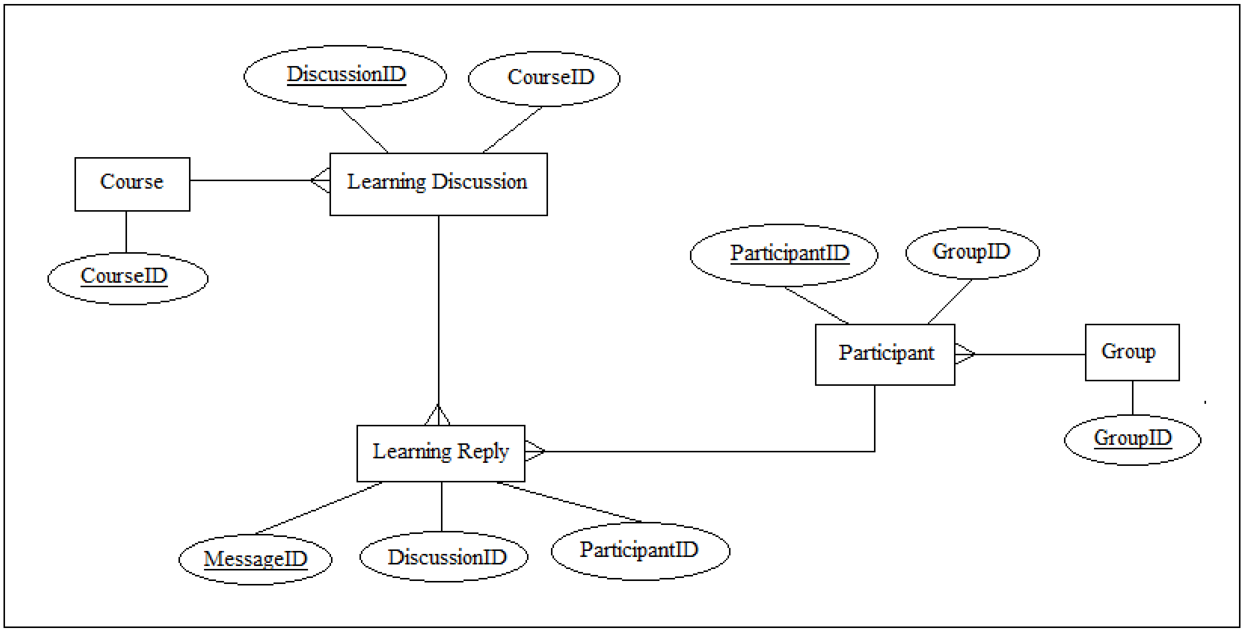


Figure 3-7: ERD for the collaborative m-learning software

The details of the tables within the ERD are explained below:

mdl_course – this table held the course data for any course created within the application. It was inbuilt within the Moodle system. Its primary key (CourseID) was used for referencing the course information within this mobile learning application.

mdl_learning_discussion – This table stored the details about any discussion created by the administrator for any subject within the learning platform (Table 3-1). Every discussion which the students participated in was created based on what they were taught.

Table 3-1: Table Structure for mdl_learning_discussion

Field	Data Type	Description
DiscussionID	Numeric	Primary Key - Unique Identifier of a discussion
DiscussionName	Text	The Title through which the discussion is identified with by the participants
CreatedBy	Text	The person who created the discussion
DiscussionProblem	Text	The group problem to be solved by the group members
CourseID	Numeric	The course to which the discussion belongs
TimeCreated	Time	The time the discussion was created

mdl_learning_participants – This table contained the data about the participants of the group discussions (Table 3-2). Each student in a discussion was first associated with the discussion to participate in.

Table 3-2: Table Structure for mdl_learning_participants

Field	Data Type	Description
ParticipantID	Numeric	Primary Key - Unique Identifier of a participant
Name	Text	The Name of the participant
GroupID	Numeric	The group that a participant belong to

mdl_learning-group – This table stored the data about the discussion groups (Table 3-3). Each discussion group was made of three members. The administrator requested the students to form groups and forward their names and groups to be added to the system.

Table 3-3: Table Structure for mdl_learning_group

Field	Data Type	Description
GroupID	Numeric	Primary Key - Unique Identifier of a group
GroupName	Text	The Name of the Group

mdl_learning_reply – This table stored the messages posted by the group discussion participants (Table 3-4). The messages were later analyzed for knowledge construction.

Table 3-4: Table Structure for mdl_learning_reply

Field	Data Type	Description
MessageID	Numeric	Primary Key - Unique Identifier of any message posted
DiscussionID	Numeric	Identifies the discussion for which a message is contributing to
Operole	Text	Optional –the role played by the participant during the discussion
Reply	Text	The actual message post
ParticipantID	Numeric	Identifies the contributor of the message
TimeCreated	Time	The time the message was posted

3.3 Development and Implementation

The agents were developed after the implementation of the database. There are various ways of constructing intelligent agents like software engineering approach, the multi-agent approach and the cognitive architecture approach (Langley, 2004). The software engineering approach was used in developing the learning facilitations as a plug-in to run on Moodle. Moodle is an open source Learning Management System (LMS) for online learning. An LMS is a software application which enables educators to manage and implement online instruction (Durairaj & Umar, 2014). The plug-in was developed for the four agents to cater for the four facilitations. The plug-in was then incorporated into the Moodle mobile system for use by the students in their experiments. The integrated agents in the prototype generated alternatives to allow students to participate on various facilitated learning approaches during group problem solving (Adla et al., 2012).

3.4 Validation and Testing of the Software Prototype

A pre-study was done to test the usability and reliability of the software using a small number of participants who were studying a subject called ‘Object Oriented Programming’. These students did not participate in the final study. The participants were first registered to use the system by the administrator, and provided with a username and a password. Once taught, they downloaded their lecture notes from their mobile phones. The participants were grouped into discussion groups of three members each and assigned a group task to solve through online discussion. Their discussion posts were stored in the systems server for analysis.

Some of the issues noted during testing of the prototype are indicated below:

Login Problems – Some participants were not able to login because of problems like incorrect setting of their passwords, giving the wrong passwords and/or usernames and forgetting their password. As a remedy, they were supplied with a set of clear instructions on how to set their new passwords: at least 8 characters, at least one lower case, at least one uppercase, at least on special character. These instructions were embedded into the system. The students were also advised to be keen when supplying the login details and to remember the use of uppercase and/or lowercase combinations. Those who forget their passwords were requested to use the password request link which was available on the learning management system.

Participation in Online Discussions Some participants (especially those in the Role playing and Guided Negotiation Groups) did not fully understand how to access and participate in the group discussions. Again, clear instructions were incorporated within the software to guide the students on how to participate in the discussions.

The results of the pre-study were used in improving the design of the software, and consequently used in improving the final application.

Another notable output of the prototype validation process was the development of a set of instructions/guidelines to assist to have an easy access and use of the prototype (Appendix 7).

Chapter 4: Methodology – Experimental Design

4.0 Introduction

The aim of this research is to investigate the effects of (a) facilitated group participation and (b) regulated group cognitive conflicts on level of group knowledge construction. The study also investigates the moderating effect of task complexity on the two relationships above. This research study was carried out in the context of a collaborative mobile learning platform extended from Moodle Learning Management System.

4.1 Research Paradigm

Every research is supported by some assumptions which define what constitutes a 'valid' research (Myers & Avison, 2002). A paradigm examines a social phenomenon from which a particular understanding can be gained or an explanation attempted (Saunders et al., 2009). There are four main research philosophies in use: positivism, interpretivism, realism and pragmatism. Experimental studies are classified as positivism since there is evidence of formal propositions, measurement of variables, hypothesis testing and drawing inferences from a sample of a target population (Myers & Avison, 2002). Thus, this research study adopted positivism research philosophy.

4.2 Research Design

A research design is an overall plan for connecting the conceptual research problem to the empirical research (Wyk, 2012). A good research design shows the research approach and the research strategy used in a research study. The research approach used in this study is deductive approach where the research starts with theory, developing the theory based on literature review, and then designing a research strategy to test the theory. The research strategy used is experiments and survey questions.

The overall design for the research study is shown in Figure 4-1

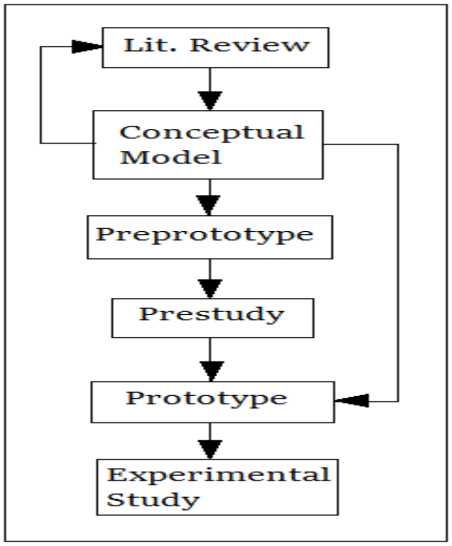


Figure 4-1: Overall Research Design

4.2.1 Overall Experimental Design

Four experimental studies were conducted. This was to help in identifying the effect of the independent variable on the dependent variable and the moderating effect on those relationships. The first experimental study investigated the effect of using facilitated group participation on the level of group knowledge construction. The second experimental study investigated the effect of regulated group cognitive conflicts on the level of group knowledge construction. The third experimental study investigated the moderating effect of task complexity on the relationship between facilitated group participation and the level of group knowledge construction, and the fourth study investigated the moderating effect of task complexity on the relationship between regulated group cognitive conflicts and the level of group knowledge construction.

The four experimental studies were by students who were taught by the lead researcher in four different courses. The courses were conducted using a hybrid learning method, i.e., using a combination of face-to-face and online learning approach. The online part was done using Moodle Learning Management System. All the learning materials (lecture notes) were downloaded from the learning platform. Additionally, other online learning activities such as quizzes, assignments, online forum, and survey are also available in this environment. As part of the research, Moodle was extended to allow for a mobile platform in order to provide support for collaborative learning specific to this research. The mobile platform had group facilitation features which were enabled or disabled appropriately depending on the specific needs of each experimental group during the study.

The overall experimental design for the research is shown in Table 4-1.

Table 4-1: Overall Research Design

Research Question	**Data Collection Approach**	**Materials and Instruments**	**Data Sources**	**Data Analysis**
RQ2	Experimental study, posttest only with control group, discussion group randomization. Had 3 groups	- Online Group Discussion Problem with facilitated group participation -Interview	-Posted Messages -Interview responses	-Content Analysis -One way ANOVA
RQ3	Experimental study, posttest only with control group, discussion group randomization, repeated measures. Had 3 groups	- Online Group Discussion Problem with regulated group cognitive conflicts -Interview	-Posted Messages -Interview responses	-Content Analysis -Repeated Measures ANOVA
RQ4	Experimental study, posttest only with control group, discussion group randomization. Had 3 groups	- Two online Group Discussion Problems with facilitated group participation	-Posted Messages	-Content Analysis -Regression Analysis
RQ5	Experimental study, posttest only with control group, discussion group randomization. Had 3 groups	- Two online Group Discussion Problems with regulated group cognitive conflicts	-Posted Messages	-Content Analysis -Regression Analysis

The students participated in group discussions after being taught and after downloading the learning materials. The purpose of having them use the platform before engaging in group discussions was to orient them and make them familiar with that environment before getting involved in the group discussions. The discussions were derived from topics earlier taught by their lecturer. All the discussions were done using the mobile application platform, which kept a log of the students' activities and stored the messages posted by the students in the system's server. The discussions were provided after 7 weeks of a 14-week semester.

The participants of the group discussions were in groups of three members each. According to Glassmeyer et al. (2011), students are satisfied and get more benefits with online discussions when they are in groups of two to four members. Also, participants in smaller groups may be more willing to participate and share learning concerns than larger groups (Terry, 2013). Groups which are very large encourage 'freeloading' where some members do not participate in solving the group problem (Clifford, 2012). All the discussion groups for all the studies were self-selected. Although random assignment increases the likelihood of heterogeneity in grouping, it does not guarantee that grouping is done according to learner's competence level (Muuro et al., 2016). Also, self-selected groups have advantages such as allowing students to converse better, have positive attitude towards collaborative learning, and feel more excited to work together (Chapman et al., 2006). This informed the choice of self-selection assignment of group members because effective conversations were a great concern to this research compared to mere group scores (group processes over group product). However, the assignment of discussion groups to the treatment groups was purely random, and the participants were blind to the treatment groups' assignment. There was no need for pre-tests because the competence levels of the groups, to hold group discussions, had been attained through self-selection. The approach taken in these experiments is more of a true experiment than quasi-experiment because the measurement of the knowledge construction was done on the discussion group and not the individuals within the group, and that's why the discussion groups were randomly assigned to treatment groups.

Participants in study 1 and 2 were provided with ill-structured group problems. As informed by the literature review, an ill-structured problem describes a scenario but does not provide enough information on how the problem can be solved i.e. the problem definition, how to break the problem down, what skills or knowledge to apply, and so on (Oboko, 2012). Such a problem may have multiple solutions or no solution at all, and may possess multiple criteria in evaluating their outcome (Kitchner, 1983) and as such elicits group discussion because it attracts different views from different members by eliciting cognitive conflicts. Thus, learners solving ill-structured problems, which have no absolute solution, must elaborate their views to their group members, and validate their opinions (Soller, 2001). Participants in study 3 and 4 used two types of problems: a well-structured and an ill-structured problem. This is because the two studies investigated the moderating effect of task complexity on the relationships postulated in study 1 and 2.

The descriptive statistics in all the studies described the number of contributions by group members and the overall structure by the participants.

4.3 Study 1 – Use of facilitated Group Participation on Group Knowledge Construction

4.3.0 Introduction

This experimental study answered research question 2 and is based on Hypothesis 1. The study aimed to establish the effect of facilitated group participation on the level of group knowledge construction. This study was done with students from a local university in Kenya. The study participants were given an explanation on how to participate in the experiment. They were assured that their participation towards the study would not be disclosed.

The students were undertaking a unit called "Data Structures and Algorithms" in a 14-week semester. All the students were registered to the system so that they could access the learning material in form of lecture notes, with each student assigned a username and a password. The lecture notes were available for downloading after the students were taught.

A total of 90 participants formed 30 discussion groups of three members each through self-selection. The participants were requested to form their own groups based on their familiarity of working with each other in previous discussions. The discussion groups were then randomly assigned to the treatment groups, that is, each treatment group assigned 10 discussion groups. This random assignment of discussion groups guaranteed that all of them had the same chance of being in any treatment condition.

Each sub-group was provided with an ill-structured group task to solve through online group discussion using the collaborative m-learning prototype. Before the discussions started, the researcher informed the students of certain expectations of desired online behavior such as no posting of personal insults or remarks, and no vulgarities in the discussions. Students made their contributions towards solving the collaborative task through text messages. All the contributions to the discussions were saved in a log file within the system's server. These logged messages identified the contributors and the discussion groups they belonged to. The online discussion was simultaneously conducted for one week for all treatment groups.

A few participants were randomly selected to participate in the survey interview with each participant taking 15 minutes.

4.3.1 Design of the Experiment

The study used a post-test control group design with random assignment of discussion groups. Multiple treatment design was used in order to deal with multiple available alternatives for facilitated participation. Three treatment conditions were used since there were two different support features used with two experimental groups and a control group using no facilitation (Oboko, 2012).

The discussion groups were randomly assigned to the treatment conditions. The treatment duration was 10 weeks. The experimental design showing the groups, treatments and observations for study 1 is shown in Table 4-2.

Table 4-2: Experimental Design showing groups, treatments and observations for study 1

Group	**Treatment**	**Posttest**
Experimental Group 1	X_1 – Use of informative feedback	O_1
Experimental Group 2	X_2 – Use of turn taking	O_2
Control Group		O_3

The difference among the treatment groups was due to the facilitated participation technique used by the students in each group during collaborative learning. Each of the facilitation could be enabled/disabled depending on the specific needs of each treatment group.

Treatment 1: The members of this group used turn taking as the technique for facilitating group participation. This facility was incorporated within the mobile application to ensure equal participation by automatically assigning each participant a turn to contribute.
Treatment 2: The members of this group used informative feedback for the facilitated group participation. The facility was also integrated within the collaborative m-learning application. This feedback was meant to motivate student to participate in the group problem solving.
Treatment 3: This was the control group. The participants in this group were not required to use either the turn taking facilitation or the informative feedback support.

4.3.2 Treatment Materials and Instruments

The instruments used in this study were an ill-structured group task and survey questions. An ill-structured problem in "Data Structures and Algorithms" course was designed to be discussed by the participants (see Appendix 2). This ill-structured problem was developed through consultations with an expert in the area of Data Structures and Algorithms. A content analysis coding scheme (discussed in section 4.7) was used in analyzing the posted messages from the online discussion.

A set of survey questions (see Appendix 6) was given to a few participants who were randomly selected immediately after the discussion forum was closed. The survey aimed at getting more insights into the issues that were not considered using the message posted during the online discussion.

4.4 Study 2 – Use of Regulated Group Cognitive Conflicts on Group Knowledge Construction

4.4.0 Introduction

This experimental study answered research question 3. The study aimed to establish the effect of regulated group cognitive conflicts on the level of group knowledge construction. A total of 30 students took part in the experimental study with all of them participating in all the treatment conditions.

The students were studying a subject called "Design and Analysis of Algorithms" for a 14-week semester. The students were first registered to use the system for accessing their lecture notes and other collaborative learning features. Each student got a username and a password at the beginning of the semester. All participants were later placed into discussion groups of three members each through self-selection. Each discussion group participated in three online discussions by solving three ill-structured problems of equal difficultness (see Appendix 3) within each of the three treatment conditions. The posted messages were saved in the system's server for later analysis.

A few of the students were randomly selected to participate in a survey interview (see Appendix 6) immediately after the closure of the online discussions. Each participant took 15 minutes for the interview.

4.4.1 Design of the Experiment

The research design used in this study was post-test only experimental study with control group. The experiment used multiple treatment design approach in order to deal with multiple available alternatives (facilitations). The treatment conditions are explained below:

Treatment 1: The members of this group used role playing as the technique for regulating group cognitive conflicts.

Treatment 2: The members of this group used guided negotiation for regulating the cognitive conflicts.

Treatment 3: This was the control group. The participants in this group used neither role playing nor guided negotiation.

Due to less number of participants in this study, crossing out of subjects with treatments was done. This made each subject to be used a number of times in the experiment. An advantage of crossing is that the participants are more likely to result in a significant effect, given the effects are real. This is because the effects of individual differences between subjects are partitioned out of the error term.

The discussion groups were randomly assigned to the three treatment conditions in the first online discussion. In the second online discussion, each discussion group was given a different treatment condition from the first one. Again, in the third online discussion, each group participated in a different treatment condition from the first and the second discussion. That is, all the discussion groups participated in the three treatment conditions. Duration of one week was observed between each online discussion.

The experimental design showing the groups, treatments and observations for study 2 is shown in Table 4-3.

Table 4-3: Experimental Design showing groups, treatments and observations for study 2

Group	Treatment	Posttest	Treatment	Posttest	Treatment	Posttest
Group 1	X_1 – Use of role playing	O_1		O_4	X_2 – Use of guided negotiation	O_7
Group 2	X_2 – Use of guided negotiation	O_2	X_1 – Use of role playing	O_5		O_8
Group 3		O_3	X_2 – Use of guided negotiation	O_6	X_1 – Use of role playing	O_9

4.4.2 Treatment Materials and Instruments

Three ill-structured group problems of same level of difficultness in the subject area of “Design and Analysis of Algorithms” were used in this study (see Appendix 3). Each of the ill-structured problems was developed in consultation with an expert in the area of Design and

Analysis of Algorithms. A content analysis coding scheme (discussed in section 4.7) was used in analyzing the posted messages from the online discussion.

A set of survey questions (see Appendix 6) was given to a few participants who were randomly selected immediately after the discussion forum was closed. The survey aimed at getting more insights into the issues that were not considered using the message posted during the online discussion.

4.5 Study 3 – Moderating Effect of Task Complexity on the relationship between facilitated Group Participation and Group Knowledge Construction

4.5.0 Introduction

This experimental study investigated the moderating effect of task complexity of the relationship between facilitated group participation and level of group knowledge construction.

Self-selection was used to group all participants into discussion groups of three members each. The discussion groups were then randomly assigned to a group task of either well-structured or ill-structured problem. Finally each of the discussion group from each of the group problems (well-structured or ill-structured) was randomly assigned to the three treatment groups. There were three treatment groups in this study: a) using turn taking, b) using informative feedback and, c) using neither of turn taking nor informative feedback.

4.5.1 Design of the Study

This study used a post-test only with control group. Two main groups were formed based on two types of group tasks (well-structured and ill-structured). Three treatment groups participated in each of these two main groups. The six groups are explained below.

Treatment 1: Well-structured problem solved with no facilitated participation
Treatment 2: Well-structured problem solved using Turn-taking facility
Treatment 3: Well-structured problem solved using Informative Feedback
Treatment 4: Ill-structured problem solved with no facilitated participation

Treatment 5: Ill -structured problem solved using Turn-taking facility

Treatment 6: Ill -structured problem solved using Informative Feedback

The experimental design showing the groups, treatments and observations for study 3 is shown in Table 4-4.

Table 4-4: Experimental Design showing groups, treatments and observations for study 3

Group	**Task**	**Treatment**	**Posttest**
Control group 1	Well-structured		O_1
Experimental group 1	Well-structured	X_1 - Turn Taking	O_2
Experimental group 2	Well-structured	X_2 – Informative Feedback	O_3
Control group 2	Ill-structured		O_4
Experimental group 3	Ill-structured	X_3 - Turn Taking	O_5
Experimental group 4	Ill-structured	X_4 – Informative Feedback	O_6

4.5.2 Materials and Instruments

Two group problems in "Human Computer Interaction" of varying complexities were developed. The first one was a well-structured problem and the second one was an ill-structured problem (see Appendix 4). The problems were developed in consultation with two experts in the area of Human Computer Interaction. A content analysis coding scheme (discussed in section 4.7) was used in analyzing the posted messages from the online discussion.

4.6 Study 4 – How the effect of regulated Group Cognitive Conflicts on Group Knowledge Construction is moderated by Task Complexity

4.6.0 Introduction

The study investigated the moderating effect of task complexity on the relationship between regulated group cognitive conflicts and the level of group knowledge construction. The discussion groups were formed through self-selection. The discussion groups were then randomly assigned to each of the two types of group tasks (well-structured and ill-structured). Finally, the discussion groups in each of the two main groups were randomly assigned to three treatment groups. The three treatment groups were control group, role playing and guided negotiation.

4.6.1 Design of the Study

This post-test only with control group experimental study had two main groups based on two types of group tasks (well-structured and ill-structured). Three treatment groups participated in each of these two main group problems. The six groups formed are given below and shown in Table 4-5.

Treatment 1: Well-structured problem solved with no controlled cognitive conflicts
Treatment 2: Well-structured problem solved using Role-playing facility
Treatment 3: Well-structured problem solved using Guided Negotiation
Treatment 4: Ill-structured problem solved with no controlled cognitive conflicts
Treatment 5: Ill -structured problem solved using Role-playing
Treatment 6: Ill -structured problem solved using Guided Negotiation

Table 4-5: Experimental Design showing groups, treatments and observations for study 4

Group	Task	Treatment	Posttest
Control group 1	Well-structured		O_1
Experimental group 1	Well-structured	X_1 – Role Playing	O_2
Experimental group 2	Well-structured	X_2 – Guided Negotiation	O_3
Control group 2	Ill-structured		O_4
Experimental group 3	Ill-structured	X_3 - Role Playing	O_5
Experimental group 4	Ill-structured	X_4 – Guided Negotiation	O_6

4.6.2 Materials and Instruments

Two types of group problems were used by the participants in this study (see Appendix 5). The two problems (well-structured and ill-structured) of varying complexities were group problems developed from a course called “Systems Programming”. A content analysis coding scheme (discussed in section 4.7) was used in analyzing the posted messages from the online discussion.

4.7 Validity and Reliability

The following measures were taken to ensure the validity of the results for the four experimental studies:

a) Participants were given prior explanation about the usage of the system, and a brief guide on how to participate in the group discussion
b) Self-selection for the group members ensured students were in groups which would allow them to converse better, have positive attitude towards collaborative learning, and feel more excited to work together (Chapman et al., 2006)
c) Random assignment of the online group discussions to the treatment conditions
d) Equal time allocated to each discussion group to solve the group task
e) Each of the discussion groups was not able to access or mingle with others during the discussion duration.
f) The features to facilitate group participation were embedded within the collaborative m-learning prototype and students were not made aware of the existence of those facilitations or their absence when solving the group problem.

Special attention was paid to experiment 2 since it was a repeated measures study with the following taken into consideration:

a) Online group discussions were randomly assigned in the first measure, and keen observation made in allocating the subsequent measures
b) Duration of one week (wash-out) was given in between the online discussions.
c) Order of the assignment to the treatment groups was randomized.

4.7 Content Analysis Coding Scheme

Since differences in the definition of the unit of analysis can affect coding decisions and comparability of outcomes with other similar studies (De Wever et al., 2006), the unit of analysis used in this research study is the message posted during the online discussion, that is, each posted message is a unit of analysis. This is because the posted message was used by the student as a theme to express an idea (Minichiello et al., 1990). The coding scheme in Table 4-

6 was adopted from Van der Meijden (2005) and used in the content analysis for this research study. The advantage of adopting a coding scheme from previous studies comes from the support of accumulation and comparison of research findings across multiple studies (Zhang & Wildemuth, 2009). Also, this coding scheme identifies specific types of cognitive contributions to the discussion such as questions, answers, information and elaborations of any contributions.

Table 4-6: Coding Scheme used for Content Analysis

Cognitive: Asking Questions (Cognitive 1) Example of use		
QTN-NXP	Asking Questions that do not require an explanation (fact or simple questions)	• How many outcomes do we get? • Is that the right answer?
*QTN-XP	Asking Questions that require an explanation (comprehension of elaboration)	• Why don't we choose another value for the pivot?
QTN-VER	Verification or asking for an agreement	• What are the leaves in your tree? • Is my explanation okay?
Cognitive: Giving Answers (Cognitive 2)		
ANS-NXP	Answering without explanation	• There are 3 types of nodes. • The main task is creating a tree.
*ANS-XP	Answering with explanation (using arguments or asking a counter-question)	• The information shows that…. • An expression tree is a binary tree because ….
Cognitive: Giving Information (Cognitive 3)		
INF-NELB	Giving information (idea or thought) without elaboration.	• Both trees are correct. • So far we have three similarities
*INF-ELB	Giving information (idea or thought) with elaboration.	• Let's now highlight the differences because…
INF-REF	Referring to earlier remark/information	• From your answer, it is true that ….
INF-EVL	Evaluating the content (summarizing/ concluding)	• So, the conclusion is .. • We have agreed that …
ACPT-NELB	Accepting contribution of another participant without elaboration.	• I agree. • You are correct.

*ACPT-ELB	Accepting contribution of another participant with elaboration.	• I agree with you because.. • Yes, but you should specify the operands on the right and the left hand sides.
NACPT-NELB	Not accepting contribution of another participant without elaboration.	• I don't think that is the cause of the problem. • I don't think that is right.
*NACPT-ELB	Not accepting contribution of another participant with elaboration.	• That is not the reason because… • I don't agree with you because…
ANY-OTHR	Any other contribution not in any of the categories above. Will include contribution (question, answer or information) which do not relate to the topic being discussed.	• Where are you members? • When is the discussion ending?

NB: All the codes with (*) indicate high level cognitive contributions

The coding scheme has three cognitive levels: Asking Questions (level 1), Giving Answers (level 2), and Giving Information (level 3).

Questions are vital in fostering knowledge construction. Questions constructively and critically engage group members into each other's thinking processes, as well as for resolving conflicting issues. There are three important functions which questions play during knowledge conflicts: a question may be a more constructive way to challenge a group member's contributions than the use of a counter argument; questions that provoke thorough elaboration and argumentation are important in fostering deep knowledge construction (Van Boxtel et al., 2000); and, questions meant to understand other members' view on a topic allow members to collaboratively and constructively resolving conflicts in groups (Galinsky et al., 2008). Engaging learners to formulate new questions and explanations is a key issue as learners are more used to finding answers to preexisting questions rather than posing new ones (Zheng et al., 2014). Repeating a contribution in a discussion allows for some form of clarification from the initial contributor. It could be a paraphrased statement, for example, "So, the operands are specified on both sides. Is that correct?" The 'agree-disagree' support encourages the discussion to continue. When any group member responds to a previous contribution (for example, “I disagree” or “I think you are right”) without an elaboration, other members should be encouraged to contribute towards the same before a conclusion is made.

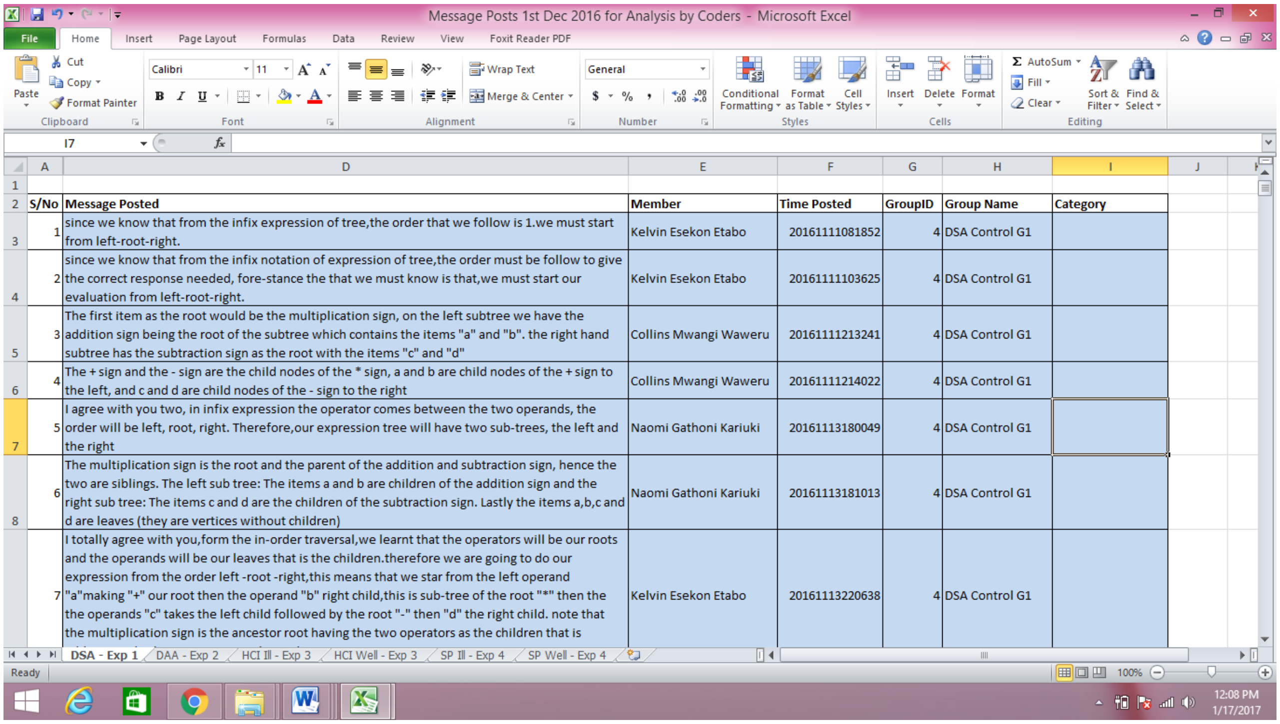
4.7.1 Validation of the Coding Scheme

A pre-study was earlier conducted as a way of testing the coding scheme for suitability in content analysis in the experimental studies. The sample data collected during the pre-study was used for validating the coding scheme. The data was used in checking the coding consistencies and the inter-coder agreement. The coding rules were revised due to low levels of consistency. Two raters were involved in coding the messages (posts) contributed by students in their group discussions. The messages were coded individually by each rater and then these codes compared. A third rater was used for independently coding the messsage posts where the two raters did not agree. The coding where the third rater agreed with either of the the two coders was adopted. The three coders came together to discuss about the codes where there was disagreement for all of them. The codes were discussed, compared and contrasted until a common agreement was reached on the suitable code for each meaning in the students' messages. The processes were repeated until all the messages were finally gathered and coded in the final coding session.

4.7.2 Inter-rater Agreement and Validation

The inter-rater reliability was calculated for acceptability of the final classification of messages. The degree of agreement used by the raters was the statistical indicator Cohen's Kappa (K), which is a percentage of agreement between independent evaluators (De Wever et al., 2006) meant to minimize subjectivity. The raters were earlier trained on how to categorize the messages posted before embarking on the coding exercise and they were also provided with guidelines on how to categorize the messages during the coding exercise (see Appendix 8).

The messages posted by the participants were sorted using two columns (by groupID to identify the group a participant belonged to, and then by TimeCreated to identify the time the message was posted and the sequence of the discussion) as indicated in Figure 4-2.



Message Posts 1st Dec 2016 for Analysis by Coders - Microsoft Excel

S/No	Message Posted	Member	Time Posted	GroupID	Group Name	Category
1	since we know that from the infix expression of tree,the order that we follow is 1.we must start from left-root-right.	Kelvin Esekon Etabo	20161111081852	4	DSA Control G1	
2	since we know that from the infix notation of expression of tree,the order must be follow to give the correct response needed, fore-stance the that we must know is that,we must start our evaluation from left-root-right.	Kelvin Esekon Etabo	20161111103625	4	DSA Control G1	
3	The first item as the root would be the multiplication sign, on the left subtree we have the addition sign being the root of the subtree which contains the items "a" and "b". the right hand subtree has the subtraction sign as the root with the items "c" and "d"	Collins Mwangi Waweru	20161111213241	4	DSA Control G1	
4	The + sign and the - sign are the child nodes of the * sign, a and b are child nodes of the + sign to the left, and c and d are child nodes of the - sign to the right	Collins Mwangi Waweru	20161111214022	4	DSA Control G1	
5	I agree with you two, in infix expression the operator comes between the two operands, the order will be left, root, right. Therefore,our expression tree will have two sub-trees, the left and the right	Naomi Gathoni Kariuki	20161113180049	4	DSA Control G1	
6	The multiplication sign is the root and the parent of the addition and subtraction sign, hence the two are siblings. The left sub tree: The items a and b are children of the addition sign and the right sub tree: The items c and d are the children of the subtraction sign. Lastly the items a,b,c and d are leaves (they are vertices without children)	Naomi Gathoni Kariuki	20161113181013	4	DSA Control G1	
7	I totally agree with you,form the in-order traversal,we learnt that the operators will be our roots and the operands will be our leaves that is the children.therefore we are going to do our expression from the order left -root -right,this means that we star from the left operand "a"making "+" our root then the operand "b" right child,this is sub-tree of the root "*" then the the operands "c" takes the left child followed by the root "-" then "d" the right child. note that the multiplication sign is the ancestor root having the two operators as the children that is	Kelvin Esekon Etabo	20161113220638	4	DSA Control G1	

Figure 4-2: Sample messages posted by the participants in the online discussion

To calculate the inter-rater agreement, each of the posted messages was categorized and given an ordinal value based on the Content Analysis Tool shown in Table 4-7. Each of the two raters categorized the posted messages independently.

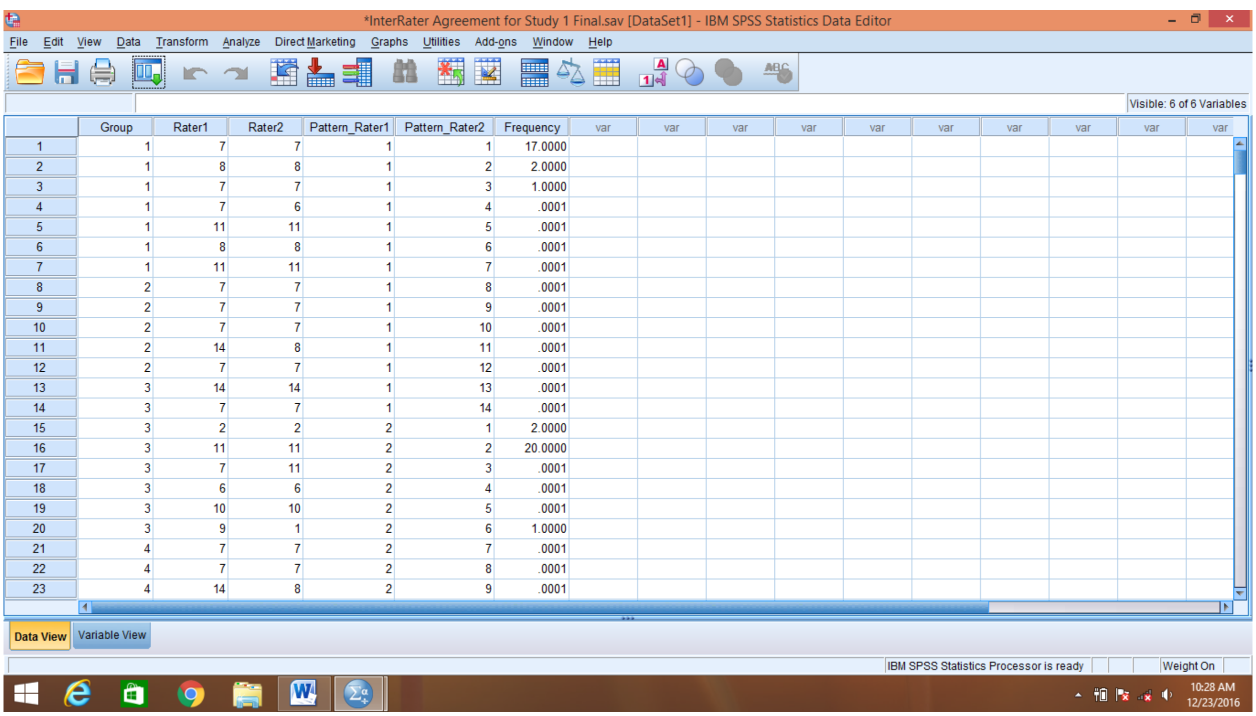
Table 4-7: Content Analysis Tool with ordinal values for inter-rater agreement

Cognitive: Asking Questions (Cognitive 1) Example of use			**Ordinal Value**
QTN-NXP	Asking Questions that do not require an explanation (fact or simple questions)	• How many outcomes do we get? • Is that the right answer?	1
*QTN-XP	Asking Questions that require an explanation (comprehension of elaboration)	• Why don't we choose another value for the pivot?	2
QTN-VER	Verification or asking for an agreement	• What are the leaves in your tree?	3

		• Is my explanation okay?	
Cognitive: Giving Answers (Cognitive 2)			
ANS-NXP	Answering without explanation	• There are 3 types of nodes. • The main task is creating a tree.	4
*ANS-XP	Answering with explanation (using arguments or asking a counter-question)	• The information shows that…. • An expression tree is a binary tree because ….	5
Cognitive: Giving Information (Cognitive 3)			
INF-NELB	Giving information (idea or thought) without elaboration.	• Both trees are correct. • So far we have three similarities	6
*INF-ELB	Giving information (idea or thought) with elaboration.	• Let's now highlight the differences because…	7
INF-REF	Referring to earlier remark/information	• From your answer, it is true that ….	8
INF-EVL	Evaluating the content (summarizing/ concluding)	• So, the conclusion is .. • We have agreed that …	9
ACPT-NELB	Accepting contribution of another participant without elaboration.	• I agree. • You are correct.	10
*ACPT-ELB	Accepting contribution of another participant with elaboration.	• I agree with you because.. • Yes, but you should specify the operands on the right and the left hand sides.	11
NACPT-NELB	Not accepting contribution of another participant without elaboration.	• I don't think that is the cause of the	12

		problem. • I don't think that is right.	
*NACPT-ELB	Not accepting contribution of another participant with elaboration.	• That is not the reason because… • I don't agree with you because…	13
ANY-OTHR	Any other contribution not in any of the categories above. Will include contribution (question, answer or information) which do not relate to the topic being discussed.	• Where are you members? • When is the discussion ending?	14

The message categories by each of the raters were tabulated and fed into SPSS using three variables (GroupID, Rater1 and Rater2). The pattern-rates for both raters were then calculated using the COUNTIFS() function in Microsoft Excel and entered to assist in calculating the Kappa value using weighted cases. The sample data entered into SPSS is shown in Figure 4-3.



	Group	Rater1	Rater2	Pattern_Rater1	Pattern_Rater2	Frequency
1	1	7	7	1	1	17.0000
2	1	8	8	1	2	2.0000
3	1	7	7	1	3	1.0000
4	1	7	6	1	4	.0001
5	1	11	11	1	5	.0001
6	1	8	8	1	6	.0001
7	1	11	11	1	7	.0001
8	2	7	7	1	8	.0001
9	2	7	7	1	9	.0001
10	2	7	7	1	10	.0001
11	2	14	8	1	11	.0001
12	2	7	7	1	12	.0001
13	3	14	14	1	13	.0001
14	3	7	7	1	14	.0001
15	3	2	2	2	1	2.0000
16	3	11	11	2	2	20.0000
17	3	7	11	2	3	.0001
18	3	6	6	2	4	.0001
19	3	10	10	2	5	.0001
20	3	9	1	2	6	1.0000
21	4	7	7	2	7	.0001
22	4	7	7	2	8	.0001
23	4	14	8	2	9	.0001

Figure 4-3: Sample data entered for calculation of inter-rater agreement

The inter-rater agreement's Kappa value for the posted messages from the prestudy was then calculated and attained a value of 0.243. A value between 0.61 and 0.80 is a substantial agreement while one between 0.81 and 1.00 is almost perfect agreement (Landis & Koch, 1977). This low inter-rater agreement value prompted for the improvement in the approach for coding the messages, which was used in the final study. A third rater was involved in categorizing the messages where the two raters did not agree. In cases where two of the three coders did not agree, a consensus was reached by the three coders.

Three independent raters were trained for three hours on how to use the content analysis coding scheme using some initial examples from the posted messages. During this training, the raters jointly coded the messages together with the researcher to familiarize themselves with the coding scheme. Also issues concerning definitions of categories, coding rules, or categorization of specific cases were discussed and resolved by the coders and the researcher. A coding manual/guide was developed by the researcher to ensure the consistency of coding (see Appendix 8). This is because the coders in the pre-study could group a message into more than one category. The coding manual consisted of category names, definitions or rules for assigning codes, and examples.

4.7.3 Calculating Group Knowledge Construction

The ranking of the codes in terms of the contribution of each posted message towards knowledge construction was done based on the type of each posted message. All the group messages were ranked and the level of knowledge construction calculated for each group. Each of the categories in the Content Analysis Tool was assigned a ranked value (score) based on the significance of the posted message to the process of group knowledge construction as indicated in Table 4-8.

Table 4-8: Content Analysis Tool with ranked values

Cognitive: Asking Questions (Cognitive 1) Example of use			**Ranked Value**
QTN-NXP	Asking Questions that do not require an explanation (fact or simple questions)	• How many outcomes do we get? • Is that the right answer?	7

*QTN-XP	Asking Questions that require an explanation (comprehension of elaboration)	• Why don't we choose another value for the pivot?	13
QTN-VER	Verification or asking for an agreement	• What are the leaves in your tree? • Is my explanation okay?	8
Cognitive: Giving Answers (Cognitive 2)			
ANS-NXP	Answering without explanation	• There are 3 types of nodes. • The main task is creating a tree.	6
*ANS-XP	Answering with explanation (using arguments or asking a counter-question)	• The information shows that…. • An expression tree is a binary tree because ….	12
Cognitive: Giving Information (Cognitive 3)			
INF-NELB	Giving information (idea or thought) without elaboration.	• Both trees are correct. • So far we have three similarities	4
*INF-ELB	Giving information (idea or thought) with elaboration.	• Let's now highlight the differences because…	10
INF-REF	Referring to earlier remark/information	• From your answer, it is true that ….	5
INF-EVL	Evaluating the content (summarizing/ concluding)	• So, the conclusion is .. • We have agreed that …	3
ACPT-NELB	Accepting contribution of another participant without elaboration.	• I agree. • You are correct.	2
*ACPT-ELB	Accepting contribution of another participant with elaboration.	• I agree with you because.. • Yes, but you should specify the operands on the right and the	9

		left hand sides.	
NACPT-NELB	Not accepting contribution of another participant without elaboration.	• I don't think that is the cause of the problem. • I don't think that is right.	1
*NACPT-ELB	Not accepting contribution of another participant with elaboration.	• That is not the reason because… • I don't agree with you because…	12
ANY-OTHR	Any other contribution not in any of the categories above. Will include contribution (question, answer or information) which do not relate to the topic being discussed.	• Where are you members? • When is the discussion ending?	0

The following criterion was used in determining the ranking of the categories:

- There were 14 values which were ranked from 0 to 13, with 0 ranked for contributions which do not relate to the discussion, and 13 assigned to the contributions with the highest contribution in in knowledge construction.
- The codes marked with a * indicate the highest level of cognitive contribution. Thus they are ranked higher than those without.
- Amongst questions, answers and information, questions were ranked the highest in a discussion because they enquire for information or require an answer, and by so doing move the discussion forward. Thus questions requiring an explanation rather than a simple answer (*QTN-XP) are ranked at 13 (the highest value).
- An answer to a question was ranked second since it signifies continuity from a previous contribution, that is, an answer cannot be given to a question not asked. The answer with an explanation (*ANS-XP) was ranked 12.
- Giving a different opinion in a discussion opens other dimensions of the same problem by different contributors. Thus, disagreeing with a previous contribution but through elaboration (*NACPT-ELB) was ranked 11
- Providing information through elaboration makes a contributor to express his opinion on the item being discussed and enlightens the others. Thus, *INF-ELB was ranked 10.

- Accepting a contribution from other members is sign of agreeing and being ready to go by the opinion of others. It's a way of bringing the discussion to an almost conclusion. Accepting by elaborating (*ACPT-ELB) was ranked 9.
- A question asking for a verification or agreement (QTN-VER) is highly placed than a question which does not require an explanation (QTN-NXP) in terms of knowledge construction. Thus, QTN-VER was ranked 8 while QTN-NXP was ranked 7.
- An answer provided without an explanation (ANS-NXP) was ranked next at 6.
- Information referring to an earlier contribution (INF-REF) keeps the discussion going compared to information not accompanied by an elaboration (INF-NELB). INF-REF was ranked 5 while INF-NELB was ranked 4.
- Information provided with intention of summarizing or concluding a discussion (INF-EVL) aims to end the discussion, thus not very significant to knowledge construction, thus ranked 3.
- Accepting a contribution without elaborating (ACPT-NELB) conclusively terminates a discussion, but not accepting a contribution without an elaboration (NACPT-NELB) leaves the discussion in suspense with members a little disoriented. ACPT-NELB was ranked 2 while NACPT-NELB was ranked 1.
- Finally any message post that does not relate to the discussion does not have any significance in the contribution to the knowledge construction in that discussion thus ranked 0.

Each of the messages categorized by the coders was matched to its ranked value. Those values were used code in calculating each group's average level of knowledge construction, which was later used for the analysis of means, variances and making comparisons.

Chapter 5: Results and Discussion

5.0 Introduction

The chapter presents the results of the four experimental studies conducted in this research. The content analysis of the posted messages collected from the online discussions in the four experiments is presented. Also, the results of the survey interview for both experimental studies 1 and 2 are also presented.

The results of this research are presented based on the research questions. Research question 1 was answered in chapter 3 where a mobile application was designed, developed, implemented and used in undertaking the four experiments discussed in chapter 4. The results for the four experiments were analyzed using SPSS 19.0 and were used in answering research questions 2, 3, 4 and 5.

5.1 Experimental Study 1 Results

5.1.0 Introduction

This study investigated the effect of facilitated group participation on the level of knowledge construction. The study used three treatment group, that is, turn taking facilitation, informative feedback facilitation and the third group using neither turn taking nor informative feedback.

The messages posted in the online discussion by the participants were stored in the system's server. An interview survey was conducted using a few randomly selected participants which took 15 minutes with each participant.

Experimental study 1 helped to answer Research Question 2, which stated:

> *Which groups of learners (those using facilitated group participation or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?*

5.1.1 Analysis of the Posted Messages

A total of 364 messages were posted by 90 students who were grouped into 30 discussion groups of three members each and who participated in an online discussion. Each of the posted messages was categorized by two independent coders separately into different knowledge level codes using a Content Analysis Tool (Table 4-7).

The inter-rater agreement's Kappa value for the posted messages was 0.723 which is a big improvement from the one attained in the pre-study (0.243). A value between 0.61 and 0.80 is a substantial agreement while one between 0.81 and 1.00 is almost perfect agreement (Landis & Koch, 1977). A third rater was involved in categorizing the messages where the two raters did not agree. In cases where two of the three coders did not agree, a consensus was reached by the three coders.

The level of knowledge construction from the posted messages was calculated for each group using Table 4-8.

i) Comparing level of knowledge construction in the treatment groups

The means and distributions of the level of knowledge construction for the posted messages by the three treatment groups are shown in Figure 5-1.

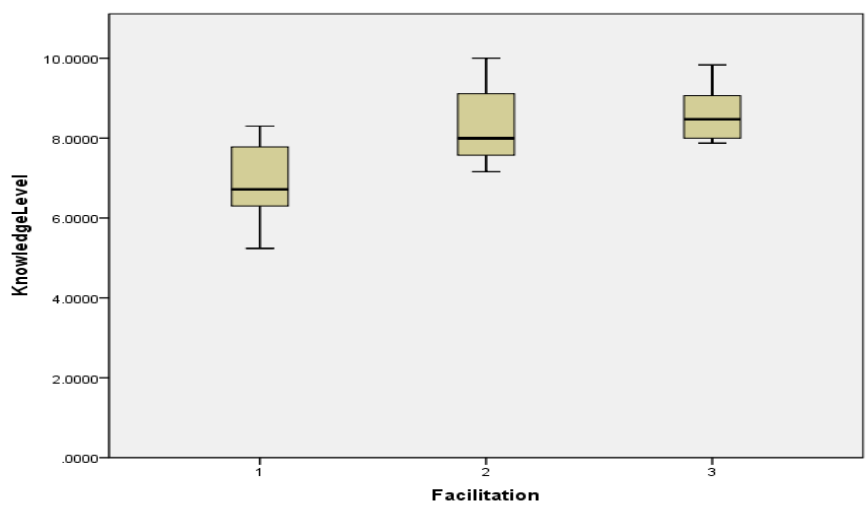


Figure 5-1: Box-plots showing comparison of means and distribution of group level of knowledge construction for the treatment groups

The mean level of group knowledge construction for the control group (1) differed from those of the other two treatment conditions namely informative feedback group (2) and turn taking group (3). The control group registered the lowest mean value of 6.906242. The mean for informative feedback group (8.359451) was slightly lower than the one for turn taking group (8.557383). The results are shown in Table 5-1.

Table 5-1: Means and variances for facilitated group participation

KnowledgeLevel

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	6.906242	.9410445	.2975844	6.233059	7.579425	5.2400	8.3000
2	10	8.359451	.9985579	.3157717	7.645125	9.073776	7.1579	10.0000
3	10	8.557383	.6672029	.2109881	8.080095	9.034671	7.8750	9.8333
Total	30	7.941025	1.1327128	.2068041	7.518063	8.363987	5.2400	10.0000

The level of knowledge construction for the control group ranges from 5.2400 to 8.3000 compared to the ones for informative feedback group which ranged from 7.1579 to 10.0000 and that of turn talking group ranging from 7.8750 to 9.8333. This shows that the treatment groups with the facilitated participation (informative feedback and turn taking groups) recorded higher levels of knowledge construction than the group without any facilitation (control group).

ii) ANOVA analysis

Analysis of Variance (ANOVA) was conducted on the groups' average ranked messages posted during the discussion after they were categorized by the independent coders. ANOVA was used because it's recommended sample size 30 and there were 30 discussion groups. The value 30 was arrived as a result of simulation studies involving the Central Limit Theorem and that a typical run chart becomes stable after 30 data points. In Table 5-2, the results showed a statistically significant difference between groups as determined by one-way ANOVA ($F(2,27) = 10.476$, $p < .01$).

Table 5-2: ANOVA analysis of the level of group knowledge construction

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	16.258	2	8.129	10.476	.000
Within Groups	20.951	27	.776		
Total	37.208	29			

Table 5-3 shows further a significant difference in the level of knowledge construction between the control group and the informative feedback group (p = 0.003), as well as between the control group and turn taking group (p = 0.001). However, there were no significant differences between the turn taking group and the informative feedback group (p = 0.871).

Table 5-3: Multiple Comparisons for the treatment groups

(I) Facilitation	(J) Facilitation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-1.4532086*	.3939410	.003	-2.429953	-.476464
	3	-1.6511410*	.3939410	.001	-2.627885	-.674397
2	1	1.4532086*	.3939410	.003	.476464	2.429953
	3	-.1979323	.3939410	.871	-1.174677	.778812
3	1	1.6511410*	.3939410	.001	.674397	2.627885
	2	.1979323	.3939410	.871	-.778812	1.174677

*. The mean difference is significant at the 0.05 level.

The Tukey post hoc test revealed that the level of knowledge construction was statistically significantly higher when using the facilitations for informative feedback (at a level of 8.36 ± .32, p = .003) and turn taking (at a level of 8.56 ± .32, p = .001) compared to the control group (neither turn taking nor informative feedback) (at a level of 6.90 ± .30).

5.1.2 Analysis of the Interview Results

An interview was conducted with some randomly selected participants after filling the self-test questionnaire. Thus, the data collected from this interview was not used to answer the research question. The survey questions (see Appendix 6) used in this study was a refinement of the pre-study. One question was removed after the pre-study was conducted. Five (5) participants were randomly selected to take part in the interview. Table 5-4 shows some sample responses from the participants.

Table 5-4: Sample Responses from the Survey

Themes	**Cited Examples**
Group Selection	I felt comfortable working in the self-assigned groups made of people I am used to
Improving the Interface	The application can be improved by adding some more graphical appearance to the interface
Motivation	We should have been provided with data bundles when the wifi was not available

Most of the respondents (80%) were comfortable with their own selection of groups to belong to. Some members suggested that some kind of motivation, such as data bundles, would have assisted in improving their contributions. Interesting suggestions were given on how to improve the system. For example, adding some graphics on user interface and improving the speed of access.

5.1.3 Summary of the Findings for Study 1

Research Question 2

> *Which groups of learners (those using facilitated group participation or those without) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?*

The use of facilitated group participation has a significant effect on the level of group knowledge construction. The informative feedback group and the turn taking group attained higher levels of knowledge construction compared to the control group. However, the turn taking group achieved a slightly higher level of knowledge construction than the informative feedback group.

5.1.4 Discussions for the Study 1 Results

From the results of study 1, there is a significant difference between the Control group and the Informative feedback group. This is due to the fact that participants were reminded of their duty to contribute in the online mobile discussion if they became passive. This greatly improved on their level of participation. While this might not have a direct impact on their improvement on the group level of knowledge construction, the limitation by other participants not to dominate the discussion could have 'forced' the dormant ones to contribute to the discussion rather than stalling the discussion. The contribution of the 'seemed dormant ones' could have ended up in improving the level of group knowledge construction through injection of new ideas into the discussion. Feedback is important in the interaction process since it increases learning and promotes creativity (Cooper, 2014). Again, according to Domalewska (2014), learners who provide feedback perform better than those who do not.

There also exist a significant difference between the control group and the turn taking group. With each participant provided with a 'time slot' to contribute towards the discussion, each member was determined to ensure that he did not delay the discussion by not responding fast enough when given the turn. Again, different ideas from multiple sources contributed to an increase in the level of knowledge construction.

The mean level of turn taking group was slightly higher than the one for informative feedback. This could be due to the fact that informative feedback was not as strict as turn taking facilitation in 'forcing' the student to participate. With turn taking a discussion could not continue unless the participants contributed in a round robin technique unlike informative feedback where a discussion could continue even if a participant delayed in contributing for a while.

5.2 Results for Experimental Study 2

5.2.0 Introduction

Study 2 investigated the effect of regulated group cognitive conflicts on the level of group knowledge construction. The study answered the research question 3 which asked:

Which groups of learners (those using regulated group cognitive conflicts or those not using) achieve higher levels of group knowledge construction in collaborative m-learning group interaction processes?

The analysis of the posted messages and the survey interview are discussed in this section.

5.2.1 Message Posts Analysis

A total of 324 messages were posted by 30 participants who participated in all the three treatment conditions. After categorizing the messages into different knowledge level codes by two independent coders using a Content Analysis Tool (Table 4-7), an inter-rater agreement of 0.716 was attained. Where the two coders disagreed, the coding of the messages was done by a third coder. The code where two of the three coders did not agree was subjected to a consensus. The average level of group knowledge construction was calculated for each group.

a. Descriptive Statistics

The mean group level of knowledge construction for the guided negotiation group (2) and role playing group (3) is higher than the one for the control group (1). In Table 5-5, the mean for the control group is 5.0001 being lower than those for both the means for Guided Negotiation (7.5367) and Role Playing (6.7202).

Table 5-5: Descriptive Statistics of Study 2

	Mean	Std. Deviation	N
Control	5.0001	2.64347	10
GuidedNegotiation	7.5367	2.28883	10
RolePlaying	6.7202	1.70702	10

b. Repeated Measures ANOVA for the Posted Messages

A repeated measures ANOVA was conducted on the messages posted during the discussion after they were categorized by the independent coders. Mauchly's test was done to check the sphericity condition. As shown in Table 5-6, the variances of the between levels of knowledge construction were not significant (significance value is 0.764 which is above 0.05). Thus, the assumption of sphericity was not violated.

Table 5-6: Maulchy's Test of Sphericity for Study 2

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Facilitation	.935	.539	2	.764	.939	1.000	.500

With sphericity not violated, Table 5-7 further shows us a significant difference in the level of knowledge construction in the three treatment groups ($F = 13.652$, $p < 0.01$)

Table 5-7: Tests of Within-Subjects Effects for study 2

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Facilitation	Sphericity Assumed	63.132	2	31.566	13.652	.000
	Greenhouse-Geisser	63.132	1.878	33.621	13.652	.000
	Huynh-Feldt	63.132	2.000	31.566	13.652	.000
	Lower-bound	63.132	1.000	63.132	13.652	.005
Error(Facilitation)	Sphericity Assumed	41.620	18	2.312		
	Greenhouse-Geisser	41.620	16.900	2.463		
	Huynh-Feldt	41.620	18.000	2.312		
	Lower-bound	41.620	9.000	4.624		

From Table 5-8, the estimated marginal mean for the control group (group 1) is 4.587± .476, the one for Guided Negotiation (group 2) is 7.953 ± .555 and the mean for Role Playing (group 3) is 7.256 ± .423.

Table 5-8: Estimated marginal means

Measure:MEASURE_1

Facilitation	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.587	.476	3.510	5.664
2	7.953	.555	6.697	9.209
3	7.256	.423	6.299	8.213

5.2.2 Analysis of the Interview Results

An interview was conducted with some randomly selected participants after filling the self-test questionnaire. The interview questions used in this study were a refinement of the pre-study. One question was removed after the pre-study was conducted (Appendix 6). Five (5) participants were randomly selected to take part in the interview. Table 5-9 shows some of the responses given by participants.

Table 5-9: Sample Responses from Survey Interview

Themes	**Cited Examples**
Group Selection	I was very comfortable with my group members since I have worked in previous discussion with my group members
Improving the Application	The application should have more features such as email communication
Motivation	The Internet speed should be improved

Most of them (60%) were comfortable with their own selection of groups to belong to. A kind of motivation, such as internet bundles, was suggested by some members. Suggestions on how to improve the system were also given.

5.2.3 Summary of the Findings for Study 2

Research Question 3

Which groups of learners (those using regulated group cognitive conflicts or those without) achieve higher levels of knowledge construction in collaborative m-learning group interaction processes?

The regulation of group cognitive conflicts affects the level of group knowledge construction. The control group achieved a lower level of group knowledge construction compared to both the guided negotiation group and the role playing group. However, the guided negotiation group achieved a slightly higher level of knowledge construction than the role playing group.

5.2.4 Discussions for Study 2 Results

The results from study 2 show a significant difference between the control group and the guided negotiation group. This is because the participants in the guided negotiation group were provided with instructions on how to conduct a group discussion and were also guided on the kind of contribution to make during the discussion. Learners themselves understand the learning content better when they provide explanations to help their fellow students understand the material (Howe et al., 2007). This way, they improve their comprehension of concepts leading to shared understanding from negotiated meaning (Lai, 2011). Thus, students who do not provide explanations do not benefit from collaboration as those who do (McLaren, 2014).

The results also indicated a significant difference between the control group and the dynamic role playing group. This is because different roles played by participants introduced different views by members at different times during the discussion which contributed to a rise in the level of knowledge construction. Again, well-coordinated groups allow participants to listen to each other's ideas and build upon them (McLaren, 2014). This was possible through dynamic roles.

Too much agreement causes relevant and important new ideas not be introduced and incorrect ideas to go unchallenged (McLaren, 2014). Research has also shown that students tend to accept opinions from their group members, not because they agree with them but merely to hasten the discussion (Rimor et al., 2010).

5.3 Experimental Study 3 Results

5.3.0 Introduction

This study investigated the moderating effect of task complexity on the relationship between facilitated group participation and the level of group knowledge construction. The research question 4 which the study answered is stated below:

> *Does the task complexity affect the relationship between facilitated group participation and level of group knowledge construction?*

The primary data collected for the study was the messages posted by the learners during the online discussions.

5.3.1 Analysis of Discussion posts

A total of 475 messages were posted by 186 participants who were in 62 discussion groups of three members each. Thirty one (31) discussion groups solved the ill structured problem (they posted 302 messages) and the remaining discussion groups solved a well-structured problem (they posted 173 messages). The inter-rater agreement's Kappa value for the ill-structured problem was 0.738 and the one for well-structured problem was 0.796. According to Landis & Koch (1977), these are regarded as acceptable values.

Regression Analysis of posted messages

The data analysis in study 3 involved testing the interaction effect between Independent Variable (type of facilitation – control/Turn taking/Informative feedback) and the moderating variable (task complexity – ill structured/ well structured). Hierarchical multiple regression was used to assess the effects of a moderating variable and if the facilitations significantly predicted the level of group knowledge construction.

In Table 5-10, the change in R^2 (R-square column) showed how much predictive power was added to the model by the addition of the variable facilitation. In this case, the % of variability accounted for went up from 59.1 % to 73.5 %. *Task Complexity* accounts for 59.1 % of the variation in the level of knowledge construction, while *Facilitation* accounts for the extra 14.4% (73.5 % - 59.1 %) of the variance (the second value in the column *R square change*).

Table 5-10: Model Summary table for Study 3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.769[a]	.591	.584	1.0873533	.591	86.561	1	60	.000	
2	.857[b]	.735	.726	.8826543	.144	32.057	1	59	.000	.685

The column for *adjusted* R^2 tells us how well the model generalizes and would like it to be very close to the value R^2. The difference for the final model is 0.9 % (73.5 – 72.6 %). Thus, if the model was derived from the population rather than the sample, it would account for 0.9 % less variance in the outcome.

From Table 5-11, both the first model (Task Complexity variable only) and the second model (Task Complexity plus Facilitation) predicted scores on the Dependent Variable (Level of Knowledge Construction) to a statistically significant degree (Both have a $p < 0.001$).

Table 5-11 ANOVA models for Study 3

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	102.345	1	102.345	86.561	.000[a]
	Residual	70.940	60	1.182		
	Total	173.285	61			
2	Regression	127.319	2	63.660	81.712	.000[b]
	Residual	45.966	59	.779		
	Total	173.285	61			

If the first set of predictors was significant, but the second wasn't, it would mean that facilitation did not have an effect above and beyond the effects of task complexity. However in this case, the initial model (model 1) has an F-ratio of 86.56 which is unlikely to have happened by chance ($p < .01$), and the second model (model 2) has an F-ratio of 81.712 which is also highly significant ($p < .01$).

Table 5-12 indicates that the predictors were statistically significant. The b values (B column) give us the relationship between knowledge construction and each predictor. The t-value indicates the level of contribution by each variable. Both task complexity t (59) = -11.46, p < .01 and facilitation t(59) = 5.66, p < .01 are significant predictors of level of knowledge construction. Task complexity had a greater impact than facilitation.

Table 5-12: Coefficients of the predictors of knowledge construction for Study 3

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	12.130	.437		27.778	.000	11.257	13.004					
	TaskComplexity	-2.570	.276	-.769	-9.304	.000	-3.122	-2.017	-.769	-.769	-.769	1.000	1.000
2	(Constant)	10.612	.445		23.873	.000	9.722	11.501					
	TaskComplexity	-2.570	.224	-.769	-11.462	.000	-3.018	-2.121	-.769	-.831	-.769	1.000	1.000
	Facilitation	.772	.136	.380	5.662	.000	.499	1.044	.380	.593	.380	1.000	1.000

The standardized beta values which are measured in standard deviation units are directly comparable and provide better insight on the predictor variables. The standardized beta values tell us that task complexity (-0.769) has a greater impact in the model than facilitation (0.380).

5.3.2 Summary of Findings for Study 3

Research Question 4

> *Does the task complexity affect the relationship between facilitated group participation and level of group knowledge construction?*

The results of the regression indicated the two predictors (facilitation and task complexity) explained 73.5 % of the variance (R^2 =.735, F(2,59) = 81.71, p < .01). It was found that task complexity significantly predicted level of knowledge construction (β= -.769, p <. 001), as did facilitation (β= .380, p<.01). As task complexity reduces the level of knowledge construction increases, and as facilitation increases the level of knowledge construction increases.

5.3.3 Discussions for Study 3

The presence of group participation was not the only determinant the level of group knowledge construction. The level of group knowledge construction was affected by both the task complexity and facilitated group participation. The complexity of the group task (or lack of it) may make the group members to compete with each other within the group or individuals to work individually by ignoring their group members (McCully et al., 2013). The reduction in the level of knowledge construction with the increase in task complexity could be due to the fact that too much complexity made students insecure (Schellens et al., 2005). Some of them perhaps got disoriented on what to contribute and even lost track of the discussion objective, maybe leading to withdrawal from the discussion.

5.4 Results for Experimental Study 4

5.4.0 Introduction

Study 4 investigated the moderating effect of task complexity on the relationship between regulated group cognitive conflicts and level of group knowledge construction in collaborative m-learning group interaction processes. Research question 5 which was associated with this study asked:

> *Does the task complexity affect the relationship between regulated group cognitive conflicts and level of group knowledge construction?*

The study used the messages posted by participants during the online group discussions for its analysis. The results of the analysis are presented below.

5.4.1 Analysis of the Posted Messages

The participants solved a group problem through an online discussion. These messages were stored in the system's server. A total of 457 messages were posted by 192 participants who were grouped into 64 discussion groups of three members each. 260 messages were posted by the group participants in 32 discussion groups who solved the ill-structured problem and 197 messages by those using the well-structured problem who were in the other 32 discussion groups. Content analysis was carried out on the messages using a content analysis tool adopted from Van der Meijden (2005) to determine the level of knowledge construction (Table 4-7). The coding of the messages was done by two independent coders. The inter-rater agreements for the two coders were 0.674 for the ill-structured problem and 0.760 for the well-structured problem. Where the two coders disagreed, a third coder classified the messages. The code where two of the three coders did not agree was subjected to a consensus.

Regression analysis of the Posted Messages

Multiple regression analysis was used to test if facilitations significantly predicted level of group knowledge construction. According to Table 5-13, the change in R^2 (R-square column) shows how much predictive power was added to the model by the addition of the variable *Facilitation*. In this case, *Task Complexity* accounts for 38.9% of the variation in the level of knowledge construction, while *Facilitation* accounts for the extra 18.8 % (57.7 % - 38.9 %) of the variance (the second value in the column *R square change*).

Table 5-13: Model Summary table for Study 4

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.624[a]	.389	.379	1.3203726	.389	39.475	1	62	.000
2	.759[b]	.577	.563	1.1078965	.188	27.062	1	61	.000

The column for *adjusted* R^2 tells us how well our model generalizes and would like it to very close to the value R^2. The difference for the final model is 1.4 % (57.7– 56.3 %). Thus, if the model was derived from the population rather than the sample, it would account for 1.4 % less variance in the outcome.

As shown in Table 5-14, both the first model (Task Complexity variable alone) and the second model (Task Complexity plus Facilitation) predicted scores on the Dependent Variable (Level of Knowledge Construction) to a statistically significant degree (Both have a $p < 0.01$);

Table 5-14: ANOVA models for Study 4

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	68.819	1	68.819	39.475	.000[a]
	Residual	108.090	62	1.743		
	Total	176.909	63			
2	Regression	102.036	2	51.018	41.565	.000[b]
	Residual	74.874	61	1.227		
	Total	176.909	63			

Thus, both the first set of predictors (model 1) and the second one (model 2) have a significant effect on the level of knowledge construction. For the initial model (model 1) the F-ratio is 39.475 which is unlikely to have happened by chance ($p < .001$), and the second model (model 2) has an F-ratio of 41.565 which is also highly significant ($p < .01$).

Table 5-15 further gives us the relationship between knowledge construction and each predictor. As task complexity reduces the level of knowledge construction increases, and as facilitation increases the level of knowledge construction increases. The t-value indicates the level of contribution by each variable. Thus, both task complexity $t(61) = -7.488$, $p < .01$ and facilitation $t(61) = 5.202$, $p < .01$ are significant predictors of level of knowledge construction.

Table 5-15: Coefficients of the predictors of knowledge construction for Study 4

		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	11.881	.522		22.764	.000					
	TaskComplexity	-2.074	.330	-.624	-6.283	.000	-.624	-.624	-.624	1.000	1.000
2	(Constant)	10.129	.552		18.333	.000					
	TaskComplexity	-2.074	.277	-.624	-7.488	.000	-.624	-.692	-.624	1.000	1.000
	Facilitation	.890	.171	.433	5.202	.000	.433	.554	.433	1.000	1.000

The standardized beta values which are measured in standard deviation units and which are directly comparable and provide better insight on the predictor variables, indicate that task complexity (-.624) has a greater impact in the model than facilitation (.433)

5.4.2 Summary of Findings for Study 4

Research Question 5

> *Does the task complexity affect the relationship between regulated group cognitive conflicts and level of group knowledge construction?*

In summary, the results of the regression indicated the two predictors (facilitation and task complexity) explained 57.7 % of the variance (R^2 =.577, F(2,61) = 41.565, p < .01). It was found that task complexity significantly predicted level of knowledge construction (β= -.624, p <. 001), as did facilitation (β= .433, p<.01). The level of knowledge construction increases as the task complexity reduces and as facilitation increases.

5.4.3 Study 4 Discussions

The presence of regulated group cognitive conflicts was not the only factor that affected the level of group knowledge construction. The nature of the group task (task complexity) also had an effect on the level of group knowledge construction. As the task complexity increases, the level of group knowledge construction reduces. Improper level of cognitive conflicts could have caused difficulties in the collaborative learning process. For example, if the conflict is excessive, it could lead to withdrawal, anxiety or frustration. An excessive conflict can even break down the learners' current internal structures (Chow & Treagust, 2013).

5.5 Summary of Findings

In summary, the results from study 1 showed a difference of group knowledge construction in the three treatments groups, that is, informative feedback, turn taking and control group. The results from the three treatment groups in study 2 (role playing group, guided negotiation and control group) also showed a notable difference in the levels of knowledge construction. In study 3, both facilitated participation and task complexity affected the levels of knowledge construction. Study 4 also showed that knowledge construction was not only determined by regulated cognitive conflicts, but also by task complexity.

The students who used the control groups for their experiments were compensated by adding them some few scores to cater for their non-use of the facilitations. Thus, they were not disadvantaged from the others.

Chapter 6: Conclusions and Further Work

6.0 Introduction

This chapter gives the conclusions of this research works based on the opinions of the researcher. It highlights the research contributions, limitations and future work from this research.

6.1 Conclusions

From research objective 1, it can be concluded that the intelligent agents can be used in Moodle Learning Management systems to facilitate collaborative mobile learning in place of human tutors. Well-designed LMSs can take advantage of intelligent agents for facilitating group learning. The use of intelligent agents was effective in collecting and analyzing the group collaboration processes.

The second research objective was to investigate the effect of facilitated group participation on the level of group knowledge construction in collaborative m-Learning group interaction processes. From study 1, it can be concluded that facilitated group participation improves the level of group knowledge construction. The use of both turn taking and informative feedback facilities resulted to improved levels of knowledge construction. Specifically, both turn taking and informative feedback were enabled by the intelligent agents through tracking the group discussion activities.

From study 2, it can be concluded that the use of both role playing and guided negotiation improves the level of group knowledge construction. Again, as in study 1, the intelligent agents are effective in collection and analysis of group interactions to dynamically regulate the group discussions.

From study 3, we conclude that the nature of the group task has a moderating effect on the relationship between the facilitated group participation and the level of group knowledge construction. However, when the task is too complexity, this negatively affects the level of group knowledge construction.

The conclusion from study 4 is that the complexity of group task has a moderating effect on the relationship between the regulated group cognitive conflicts and the level of group knowledge construction. Again, as in study 3 task complexity negatively affects relationship when the group task is very complex leading to reduced levels of group knowledge construction.

In general, the successful implementation of the facilitations suggests that the existing LMSs such as Moodle can be improved using intelligent agents. Such a contribution is timely because most HLIs are faced with lack of instructor support in mobile learning. The use of intelligent agents leads to minimum intervention by the instructor when providing instruction support.

Based on the constructivist theory, learning occurs when learners are actively engaged in the process of knowledge construction supported by multiple perspectives facilitated by social interactions, as opposed to just being passive recipients of knowledge (Bhattacharjee, 2015). This research concludes that the used of intelligent based facilitations ensures the active construction of knowledge by the participants, as evidenced by high levels of knowledge construction in facilitated instances. This was by ensuring that they participated and got guided through the learning process. On the social-cognitive perspective, cognition is a viewed as a group process with learning and knowledge being shaped by the interactions (Bandura, 2001). With encouraged participation and guidance, the learners got more engaged and had effective interactions which led to improved levels of group knowledge. This group cognition is made more effective by equal participation in the group task.

6.2 Research Contributions

The aim of this research was to investigate the effect of facilitations on the group knowledge construction. The contributions made by this research are categorized as theoretical, pedagogical and technological contributions: Theoretical contributions leads to building of a new theory about the need to facilitating group learning processes (interactions), pedagogical contributions led to the improved group interactions, and consequently higher levels of group knowledge construction, and computer science contributions are in the area of designed and developed software prototype for collaborative m-learning through a novel architecture using intelligent agent in the research study.

6.2.1 Theoretical Contributions

This study is an addition to the current literature review available in the area of collaborative mobile learning, especially on the need to monitor and facilitate group learning processes. The conceptual framework developed will assist other researchers in this field to advance their research especially in collaborative learning processes. The adopted tool and other instruments developed and used in the study can be used in other related studies. The future work suggested in the study can also form a basis for extension of the body of knowledge in collaborative m-learning.

Learners become knowledge-generators rather than knowledge consumers through negotiation of meaning (Porcaro, 2011). This is in line with the aim of constructivist approach of facilitating students' construction of their knowledge (Mthembu & Mtshali, 2013). Thus, this research has contributed towards the constructivism theory by showing that facilitated interactions leads to improved knowledge construction.

Within the socio-cognitive context, cognitive conflicts which occur during collaboration are critical in triggering knowledge creation. It is through social interactions where such conflicts are facilitated leading to advanced levels of learning (Lai, 2011). The social cognitive theory advocates for an active learning environment where students get highly engaged through social interactions with peers, instructors, and content. Research has shown that higher interactivity in collaborative environments leads to better learning outcomes and contentment over less interactive ones (Mahle, 2011). This research has contributed to the socio cognitive theory by indicating how the cognitive conflicts can be managed effectively to increase levels of knowledge construction.

In the Interaction equivalence theorem, student-instructor interaction defines the communication between instructor and student in form of counsel, support and encouragement provided by the instructor to the student (Moore & Kearsley, 2012). This research has contributed towards the theorem by showing how the automated instructor-support can be provided in the absence of the human instructor.

6.2.2 Pedagogical Contributions

Evaluating collaborative group interactions and use of interventions to provide facilitations to improve collaboration makes a big impact in the collaborative learning. The automatic facilitations provided for group discussions relieve the human facilitator from the trouble of always being there to manage the discussion. Turn taking and informative feedback have proved to be good facilitations for encouraging students to contribute to the group discussions and consequently improving the group knowledge construction. Again, the study has contributed in some of the ways of regulation group cognitive conflicts through role playing and guided negotiation resulting to higher levels of knowledge construction. These contributions have indicated the need to seriously consider the group facilitations and interventions in the design of collaborative learning software.

6.2.3 Computer Science Contributions

The use of intelligent agents to implement the group facilitations in the Moodle mobile platform provides a different approach to improving collaborative learning. This can be considered, not just as an extension of the Moodle mobile platform, but in the entire range of LMSs, both online and mobile based. A new mobile architecture called Collaborative M-learning Agent-Based Architecture (CMABA) which was developed and implemented in this research study for facilitating group interactions through intelligent agents is a significant contribution to the design of collaborative mobile software systems. Designers can use, modify or extend the architecture in their research in agent based collaborative mobile systems. Though the architecture is based on the Moodle platform, it can be modified to run on other Learning Management platforms.

6.3 Limitations

There were a number of limitations encountered in this research. First, the both the number of targeted learners was less and the target population was limited. In particular, there was a shortage of participants for study 2 since those enrolled for that unit did not meet the required number for an experimental study. However, a repeated measures approach was adopted for the study to cater for that deficit.

Second, the non-probability sampling was used in selecting the respondents from the target population. Purposive sampling was used as the only feasible option. Also, the self-selection approach used in creating the discussion groups was not very good approach of creating heterogeneous groups. However, the self-selection approach produced groups of learners with equal competence levels.

Thirdly, with relation to the survey interview, the study relied on the truthfulness and the honesty of the respondents in the self-reporting. Though there is no suggestion that there was under or over exaggeration in the responses, it would have been more authentic if gauged directly from examining the system logs.

6.4 Further Work

Further work is recommended in order to extend the findings of this research. The following are recommended.

First, the study can be done under different sets of conditions and environments. Since the study was done using smart phones, there is need to implement and evaluate the application using other mobile devices such as personal digital assistants (PDAs).

Secondly, improvements need to be done on the existing mobile application which was used in the study to determine whether the level of group knowledge construction can be further improved. For example, turn taking would be improved by considering providing alerts to the students in order not to delay the others as they wait for the turns of one of them, that is, not to have a suspended discussion due to a delay by one member. Also, participatory feedback can be improved by providing students with statistics on the type of contributions they make during the group discussion (e.g. 20% Answers without Elaboration, 50% Information without explanation, 30% Questions which require explanations) which may raise their awareness and improve the group knowledge construction. Guided negotiation can also be considered in the context of group problem solving process where the guiding facilitation can apply based on those stages of group problem solving.

Thirdly, the agents within this research operate autonomously without sharing their data. The work can be extended to have them work together in a setup similar to a Multi-Agent System (MAS). This would greatly improve the Leaning Management Systems (LMS).

Fourthly, more research needs to be done to determine whether there exist other approaches which can be used for better results compared to intelligent agents in facilitating group interactions.

Lastly, the implementation of the facilitated interactions can be extended to other LMS platforms, other than in Moodle LMS.

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Publications and Conference Proceedings

Publications

The following Journal Paper was published before the defense of this research work:

- Stephen T. Njenga, Robert O. Oboko, Elijah I. Omwenga, Elizaphan M. Maina, "**Use of Intelligent Agents in Collaborative M-Learning: Case of Facilitating Group Learner Interactions**", International Journal of Modern Education and Computer Science (IJMECS), Vol.9, No.10, pp. 18-28, 2017.DOI: 10.5815/ijmecs.2017.10.03. Available at http://www.mecs-press.org/ijmecs/ijmecs-v9-n10/IJMECS-V9-N10-3.pdf

Conference Papers

The first conference paper was published in the IEEE Africon 2018 conference proceedings before the defense of this work, while the second paper was already slotted in the IST-Africa conference 2018 programme but was awaiting the presentation in the that conference.

- Stephen T. Njenga, Robert O. Oboko, Elijah I. Omwenga, Elizaphan M. Maina. **Regulating Group Cognitive Conflicts using Intelligent Agents in Collaborative M-Learning**. IEEE Africon 2017 Proceedings. pp 44-49.
- Stephen T. Njenga, Robert O. Oboko, Elijah I. Omwenga, Elizaphan M. Maina. **Facilitating Group Learner Participation using Intelligent Agents in Collaborative M-Learning**. ISTAfrica Conference 2018. May 9-11, 2018 at Gaborone, Botswana.

Appendices

Appendix 1: Ill-Structured Problem for the Pre-Study

Group Discussion Problem

Given:

John is a student and that a student is a human being.

Required:

Use the discussion forum provided in the moodle learning platform to discuss how you can represent this kind of class relationship by proposing some fields and methods you may include as its members. It's not necessary to draw the class diagram.

NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Appendix 2: Ill-Structured Problem for Study 1

Group Discussion Problem

Given:

There are many sorting algorithms one can use to sort the list given below:

4, -2, 10, 5, 7, 3, 2, 8, 1

Required:

Within the discussion forum provided in the moodle learning platform, use any sorting algorithm to discuss how the above data can be sorted, and justify why you have chosen that algorithm.

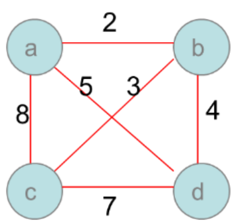
NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Appendix 3: Ill-Structured Problems for Study 2

Group Discussion Problem 1

Given:

Below are four cities with known distances between each pair.



Required:

In the moodle discussion forum, use exhaustive search to discuss and find the shortest tour that passes through all the cities exactly once before returning to the starting city.

NB: Please make contributions which ONLY relate to solving the problem given above. Your message posts SHOULD be in English.

Group Discussion Problem 2

Given:

You are provided with three matrices whose dimensions are given as: A (4x100), B (100x6) and C (6x50).

Required:

In the moodle discussion forum, discuss and determine the best way to group the matrices (paranthesization) to produce the minimum number of operations to calculate the matrix product.

NB: Please make contributions which ONLY relate to solving the problem given above. Your message posts SHOULD be in English.

Group Discussion Problem 3

Given:

You are provided with the infix expression a + b(c-d).

Required:

Use the mobile learning platform to discuss how you would create an expression tree from it. Just indicate your tree in levels: starting from the root downwards. For example x is the root, y is the child of x, etc. There is no need of drawing the tree. The final tree should be a well explained tree from the root to the leaves.

NB: Please make contributions which ONLY relate to solving the problem given above. Your message posts SHOULD be in English.

Appendix 4: Well-Structured and Ill-Structured Problems for Study 3

Well-Structured Group Problem

Given:

An interface is required by the university management to be used by students to enter their registration data when they report to the university.

Required:

As a group, discuss and recommend features to be captured in the interface to assist the student when interacting with the system. Consider all the issues you have covered in HCI so far. **NB**: You need not to draw the interface itself.

NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Ill-Structured Group Problem

Through the moodle online discussion forum, discuss and suggest the sub-tasks within "Student Registration" task and develop a textual Hierarchical Task Analysis (HTA) description for that task.

NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Appendix 5: Well-Structured and Ill-Structured Problems for Study 4

Well-Structured Group Problem

Within moodle discussion forum, give the general steps you would follow when using the open() system call to create a regular file in UNIX, and consequently develop a simple program example.

NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Ill-Structured Group Problem

Within moodle discussion forum, use examples to compare and contrast the use of mknod() and open() system calls in creating files within UNIX operating system.

NB: Please make contributions which ONLY relate to solving the problem given above. Your contributions (message posts) MUST be in English.

Appendix 6: Survey Interview Questions

	Questions
1.	Did you feel comfortable working in your assigned groups?
2.	How would you have preferred to be assigned to groups?
3.	Did you get enough time to complete the discussion task?
4.	Did it take unnecessarily long time to start the discussion?
5.	Which kind of difficulties did you encounter before starting the discussion?
6.	Do you think that all the opinions in the group members were valued?
7.	Do you think the communication between the group members was effective? How would you rate it 1-10?
8.	Do you think the conflicts not related to the topic being discussed amongst members were dealt with in an effective way?
9.	What do you think you needed to do to hold all members accountable (own the discussion) in the group?
10.	What ways would you recommend on improving the system?
11.	Do you think you remained focused on the problem you were solving?

Appendix 7: Instructions on how to participate in the Online Discussions

To participate in the online discussion

1. Firstly, you need to Login in to the system
    a. Go to: www.njenga.or.ke/moodle, using your mobile phone.
    b. Click Log in link, type your username and password, and then click **Log in** Button. When you have successfully logged in, your name will appear at the top of the site.
    c. From the list of subjects, click the Subject you are registered for. From there you can download your notes and also access the discussions.
    d. To participate in a discussion, click it once.
    e. This opens another page with a message “Welcome to MLearning” caption. Click the discussion **link** below that caption.
    f. The actual discussion opens with instructions about the discussion problem. Please read the discussion carefully and understand it before you start posting messages.
2. Secondly, to Post messages into the discussion forum depends on the group you are assigned to. You must note the group you belong to and the instructions on how to participate in the discussion for that group. These instructions are in the top section of the page.
    a. Control Groups
        i. Click the Post Message link, and scroll down to the **Reply** section where you type your message.
        ii. Click the **Submit** button after to submit your message.
        iii. You may be required to **refresh** your page often to see the posted messages
    b. Turn Taking Groups
        i. Each participant is given a chance to participate. You cannot post two consecutive messages before your group members post.
        ii. Click the Post Message link, and scroll down to the **Reply** section where you type your message.
        iii. Click the **Submit** button after to submit your message.
        iv. You may be required to **refresh** your page often to see the posted messages
    c. Informative Feedback
        i. Click the Post Message link, and scroll down to the **Reply** section where you type your message.
        ii. Click the **Submit** button after to submit your message.
        iii. You may be required to **refresh** your page often to see the posted messages

d. Role Playing Groups
    i. Click the Post Message link, and scroll down to the **Reply** section where you type your message.
    ii. Click the **Reply** button which will open a **Role playing** page.
    iii. **Select the role** you are playing and then **type the message.** Then click **Submit** button. Then click the Close Window button.
    NB: You must identify your role in each message that you post.

e. Guided Negotiation Groups
    i. Click the Post Message link, and scroll down to the **Reply** section where you type your message.
    ii. Click the **Use hint** button which will open a **Guided Negotiation** page.
    iii. **Chose the contribution** you are making and then **type the message. You may/may not type an elaboration/explanation** for your contribution
    iv. Then click **Submit** button. Then click the Close Window button.
    NB: You must identify the type of message that you post.

3. **NB**: You will not be able to know the group participants unless you participate in the discussion

Appendix 8: Instructions for Coding Data

Instruction for Data Analysis

1. Provided is an excel data containing some messages which were posted by students who participated in group discussions (attached in email).
2. The posts have their groups indicated by different colouring.
3. The intention is to classify each of the messages posted into a certain category using the Content Analysis Tool which is provided as a separate document –attached in email
4. Each message is treated as a unit of analysis and can **only belong to one category**.
5. If a message, by any chance, belongs to more than one category, it is classified into the one with the highest cognitive level (indicated by an asterisk *).
6. The grouping (colouring) will assist in the classification since some posts are follow-ups of previous posts within the same group members.
7. An empty column (named "**Category**") is provided for you to fill the category which best fits a message.

Proposed procedure for Classification

1. Broadly classify the post as a Question, Answer or Information. An answer must be preceded by a question (is a show of relationship between two posts in the same group).
2. Proceed with further classification as detailed in the classification tool. Care is to taken when classifying Information, since there is a wide range of possibilities, unlike Question or Answer.

Appendix 9: Authorization to conduct Research

This appendix contains a research permit and research authorization to conduct research from NACOSTI. It also contains letters of authority to conduct research from various institutions of higher learning.

THIS IS TO CERTIFY THAT:
MR. STEPHEN THIIRU NJENGA
of UNIVERSITY OF NAIROBI, 0-520
Nairobi, has been permitted to conduct
research in *Muranga , Nairobi, Nyeri Counties*

on the topic: *FACILITATING LEARNER GROUP INTERACTIONS USING COMPUTER INTELLIGENCE IN COLLABORATIVE MOBILE LEARNING*

for the period ending:
7th November, 2017

Permit No : NACOSTI/P/16/8966/14063
Date Of Issue : 14th November, 2016
Fee Recieved :Ksh 2000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
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Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/16/8966/14063**

Date: **14th November, 2016**

Stephen Thiiru Njenga
University of Nairobi
P.O. Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Facilitating learner group interactions using computer intelligence in collaborative mobile learning,"*** I am pleased to inform you that you have been authorized to undertake research in **Murang'a, Nairobi and Nyeri Counties** for the period ending **7th November, 2017.**

You are advised to report to **the Vice Chancellors of selected Universities, the County Commissioners and the County Directors of Education , selected Counties** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. M. K. RUGUTT, PhD, HSC.
DIRECTOR-GENERAL/CEO

Copy to:

The Vice Chancellors
Selected Universities.

The County Commissioners
Selected Counties.

Stephen Thiiru Njenga,

c/o Computer Science Department,

Dedan Kimathi University of Technology.

Phone : 0722383053.

Email: njengast@gmail.com

DEPUTY VICE - CHANCELLOR RECEIVED 26 MAY 2016 De. K. U. T RTMCL

DEPUTY VICE - CHANCELLOR RECEIVED 19 MAY 2016 De. K. U. T RTMCL

19th May 2016.

DEDAN KIMATHI UNIVERSITY OF TECHNOLOGY RECEIVED 26 MAY 2016 VICE CHANCELLOR P.O. Box 657 - 10100, NYERI

The Vice Chancellor,

Dedan Kimathi University of Technology.

P.O Box 657 - 10100

Nyeri.

(3) Approved 6/6/2016

(2) Forwarded 26/5/2016

Through,

The Deputy Vice Chancellor (RTMCL),

Dedan Kimathi University of Technology,

P.O Box 657 - 10100

Nyeri.

(1) MR NJENGA
Attach approval to conduct research from NACOSTI
23/5/16

Dear Sir,

REF: AUTHORITY TO CONDUCT PHD RESEARCH IN THE UNIVERSITY

I am currently a part time lecturer in the Department of Computer Science for the period between May and August 2016.

I am kindly requesting for permission to conduct data collection with students from the School of Computing and Information Technology. I am currently a Phd. Computer Science student in the University of Nairobi.

Your permission and support in the exercise will be highly appreciated.

Yours Faithfully,

Njenga S.T.

DEDAN KIMATHI UNIVERSITY OF TECHNOLOGY RECEIVED 23 MAY 2015 SCHOOL OF COMPUTER SCIENCE & INFORMATION TECHNOLOGY

Stephen Thiiru Njenga,

C/o Computing and Information Technology Department,

Murang'a University of Technology.

10th October 2016.

DEPUTY PR... ACADEMIC RESEARCH, INNOVATION & EXTENSION MURANG'A UNIVERSITY COLLEGE IS ISO ...
10 OCT 2016
RECEIVED
P. O. Box 75-10200, MURANG'A
TEL: 0771463 515, Email: info@mruc.ac.ke

The Deputy Vice Chancellor (ARIE),

Murang'a University of Technology,

P.O Box 75-10200,

Murang'a.

Mr. Njenga,
This is approved. Please proceed.
10/10/2016

Dear Sir,

REF: REQUEST TO CONDUCT DATA COLLECTION

I am currently a member of staff in the School of Computing and Information Technology in Murang'a University of Technology. I am also a Phd. Computer Science student in the University of Nairobi.

I kindly seek your permission to perform my data collection for the Phd. with the students in our school. These are the students I am currently teaching and the data to be collected is related to what they have learnt using ~~an~~ a mobile learning platform.

Your permission and kind support will be highly appreciated.

Your Faithfully,

Njenga S.T.

Phone No:
0722 383053

KENYATTA UNIVERSITY

OFFICE OF DEPUTY VICE-CHANCELLOR, RESEARCH, INNOVATION AND OUTREACH

P. O. Box 43844 – 00100
Nairobi. Kenya
Tel. 254-20-810901 Ext. 026
E-mail: dvc-rio@ku.ac.ke

Ref: KU/DVCR/RCR/VOL.3/9

Mr. S. T. Njenga,
C/O Dept. of Computing & Info Technology
Kenyatta University
Nairobi

22nd November, 2016

Dear Mr. Njenga,

RE: REQUEST TO COLLECT RESEARCH DATA AT KENYATTA UNIVERSITY

This is in reference to your letter dated 14th November, 2016 requesting for authorization to collect research data at Kenyatta University on the topic: *Facilitating Learner Group Interventions using Computer Intelligence in Collaborative Mobile Learning* towards a PhD degree of the University of Nairobi.

I am happy to inform you that the Vice-Chancellor has approved your request to collect data. It has been noted that your data will be collected mainly from the Dept. of Computing & Info Technology.

The University requires that, upon completion of your thesis/project, you submit a bound hard copy to the Deputy Vice-Chancellor, Research who shall forward it to the University Library. Kindly therefore complete Form RIO3 and return it to my office prior to the collection of data.

Yours Sincerely,

Prof. F. Q. Gravenir
Deputy Vice-Chancellor
Research, Innovation & Outreach
cc. Vice-Chancellor
Chairman, Dept. of Computing & Info Technology