Effect of Heterogeneous Grouping on the Mathematics Achievements of Low-Ability Primary School students in a Computer Supported Collaborative Learning Environment using the Math Learning Collaborator

James Agwu Ndukwe

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I certify that this dissertation which I now submit for examination for the award of MSc in Computing (Advanced Software Development), is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the test of my work.

This dissertation was prepared according to the regulations for postgraduate study of the Dublin Institute of Technology and has not been submitted in whole or part for an award in any other Institute or University.

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1 ABSTRACT

This research examines the effects of heterogeneous grouping (the mixing or grouping of students of different academic ability) on the mathematics achievements of low-ability primary school students in a computer supported collaborative learning environment.

Improving the learning of under-achieving students in mathematics poses a significant issue in primary schools. According to most existing research, heterogeneous groups benefit lower-ability students by giving them access to the intellectual resources of higher-achievers, and low-ability students learn more in heterogeneous groups than in homogeneous and individual or separated groups.

Computer supported collaborative learning environment is an environment in which collaborative learning is more easily achieved via a designed artefact and ICT (information and communication technologies) e.g. a combination of computing devices, communications devices, designed applications etc. Collaborative learning allows learners engage in a common task, creating knowledge by sharing experiences.

With this in mind, a research was conducted on sixteen fourth-class primary school students by introducing a system called Math Learning Collaborator (MLC), which was deployed on seventeen laptop computers (sixteen for the students and one for the teacher). The students were divided into four groups consisting of four students each. Results from the research design experiment suggested that the mathematics achievement of the low-ability primary school students in the heterogeneous groups improved than those in the homogeneous and separated groups.

Key words: Heterogeneous Grouping, Homogeneous Grouping, Separated Grouping, Computer Supported Collaborative Learning, Mathematics Achievement, Low Ability Students, high Ability Students.

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1. Introduction

1.1 Background

Collaboration is a mutual commitment of members of a small group to coordinate their efforts in order to solve a problem (Roschelle & Teasley 1991). In its ideal form, collaboration involves the mutual engagement of learners in a coordinated effort to solve a problem or acquire new knowledge together (Lehtinen et al. 1999). As such, collaborative learning is a method that is in line with the new conceptions of learning and opposed to the traditional 'direct transmission' model, in which learners are assumed passive, receptive and isolated receivers of knowledge and skills delivered by an external source (Verschaffel et al. 1998).

It have been demonstrated that a collaborative learning environment confers benefits in the achievement of learning objects (Johnson & Johnson 1999), social results (group communication, problem solving, and consensus), and positive interdependence and motivation (Chambers & Abrams 1991; Newcomb & Turner 1965). Furthermore, in such an environment students can acquire new skills, ideas and knowledge by working together to build solutions to educative problems (Webb 1995; Webb & Farivar 1999; Webb & Palincsar 1996). Small-group collaborative learning activities are an integral part of classroom instruction in elementary schools (Macintyre & Ireson 2002). These activities vary in nature and are particularly employed in mathematics and language tasks aimed at attaining specific limited or simple objectives that require social interaction of all the participants in a group to arrive at jointly agreed responses.

Collaborative learning is a teaching style that has evolved over the last thirty years and is still evolving. Face-to-face teaching allows students to actively interact by sharing experiences and knowledge and take on asymmetric roles. This comes from the idea that learning is a naturally social process during which the participants talk among themselves with learning occurring through the discussion (Gerlach 1994). The participants have to be divided into learning groups for collaborative learning to be effective (Barkley et al. 2004). Some people use the terms "collaborative learning" and "cooperative learning" interchangeably, but these two terms are quite different. In fact, Dellenbourg and Schneider (1995) made a distinction between cooperative and collaborative learning. They stated that cooporative learning is a protocol involving the advance splitting of a task into subtasks that participants solve independently, while collaborative learning is a situation in which two or more participants develop synchronously and interactively a joint solution to a problem. With the advent of pervasive devices (e.g. laptops, smart phones etc.) and desktops, a computer supported collaborative learning environment is possible.

Computer-Supported Collaborative Learning (CSCL) is concerned with meaning and the practices of meaning making in the context of joint activity, and with the ways in which these practices are mediated through designed artefacts (Koschmann 2002). The concern for a process-oriented account of collaboration underlies most research on CSCL during the last decade (Dillenbourg et al. 1996), from individuals to dyads (pairs), to finally larger social contexts in which groups interact with other groups to produce learning and create knowledge (Engestrom 2004). The processes and practices of meaning-making focus on the social practices of joint meaning making, rather than individuals' practices in social settings.

CSCL makes different environments and mediation elements for social interaction and learning support available for members of a collaborative group (Silverman 1995). It is considered one of the most promising innovations to improve teaching and learning with the help of modern information and communication technology (De Corte 1996).

The role of an instructor (teacher) plays a part for a successful collaborative learning activity. The instructor's role should be to observe, monitor, facilitate, provide information, organise, restructure activity and scaffold the students by dialoguing with them (Harasim et al. 1995; Teles et al. 2001; Postholm 2006).

An effective learning has to adopt a theory of knowledge, and there has been many debates as which theory of knowledge collaborative learning adopts. According to Bates and Poole (2003), there are two theories of knowledge: objectivism and constructivism. Objectivism is the belief that there is an objective set of facts, principles and theories that have been discovered or will be discovered. On the other hand, Bates and Poole (2003, p.28) notes, "*Constructivism is the belief that knowledge is essentially subjective in nature, constructed from our perceptions and mutually agreed upon conventions. According to this view, we construct new knowledge rather than simply acquire it via memorization or through transmission from those who know to those who do not know. We construct meaning by* *assimilating information, relating it to our existing knowledge and cognitively processing it, that is, thinking about it.*"

Collaborative Learning adopts the theory of constructivism, which stresses the social interaction in knowledge creation. Piaget (1929), who pointed out that collaborative learning parallels constructivism from the research he conducted for more than six decades based on the framework he termed "genetic epistemology", showed this in very early research.

Grouping of students for effective collaborative learning is mandatory. The criteria for grouping students has been an issue, Tinzmann et al. (1990) suggest the criteria of putting students of different cultures and experiences together so that they can learn from each other's experience. Johnson and Johnson (1999) and Race (2000) suggest the following group composition criteria as shown in Table 1.1.

Grouping Criteria	**Description**	**Objective**
Random	Students are grouped according to the course attendance list (Race 2000). This criterion is used at the start of the activities as a base criterion for the experimental group, and the sole criterion for the control group	To achieve social and academic heterogeneity
Preference	Students are grouped according to affinity with their classmates	That students work comfortable by reducing the students' choice heterogeneity
Achievement	Students are grouped according to their academic performance. The two best (worst) students are grouped with the worst (best) one	Use academic heterogeneity to foster learning within the group
Sociability	Students are grouped according to an affinity scale defined by the teacher	Reducing social heterogeneity aims to encourage poorly evaluated students' social skills

Table 1.1: Student Grouping Criteria (Johnson & Johnson 1999; Race 2000)

[Note: The third grouping criteria "Achievement" is employed in the research]

Various authors (Dalton et al. 1989; Beane & Lemke 1971; Hooper & Hannafin 1988; Webb 1982) have shown that different grouping criteria for small groups affect the learning performance and social behaviour of the activity members.

According to Dalton et al. (1989), there is a need for further research on the relationship between the composition of a group and its functioning and performance depending on the type of activity and the group's characteristics, knowledge, and skills. Web et al. (1997) have raised the matter of equity in learning and social behaviour in heterogeneous groups and the opportunity to learn from others, pointing out that all children should participate and learn irrespective of race, gender, preferences, or achievement level.

Existing research on the effects of group composition on social and learning performance yields complex results. Most of this work was carried out over long periods and does not allow for simple predictions (Leonard 2001; Macintyre & Ireson 2002). However, Webb et al. (1997) found that group composition introduces a possible source of inequity in that its impact on learning will vary even among students of similar performance levels.

According to Macintyre and Ireson (2002), grouping has generally been determined by student achievement, with students placed in heterogeneous (mixed ability) or homogeneous (same ability) groups with a view to reducing the heterogeneity of learning and social behaviour in the classroom (Gregory 1984). Teachers generally decide on the groupings to be used based on research findings regarding the most successful grouping strategies. This has been a major issue in the debate about how to raise grouping standards in education (Budge 1998a, 1998b; Evans 1998).

There is substantial evidence that collaborative learning may promote equity in learning and acquisition of social skills. Slavin (1987) found that assigning students of different ethnic backgrounds to work together was consistently related to positive racial attitudes and behaviours, and also reduced the academic achievement gap between minority and majority students. The CSOS Report (1983) confirmed that collaborative education enhances educational equity. Nevertheless, little is known about how group composition actually influences the performance and processes of collaborative learning groups (Leonard 2001; Webb et al. 1997).

Some combinations of students may have advantages over others in terms of students' learning. Most empirical research on group composition has focused on the mixture of achievement levels, and it is widely believed that heterogeneous groups benefit lower-achieving students by giving them access to the intellectual resources of higher-achievers. According to Webb et al. (1997), studies showed that low-achieving students learn more in heterogeneous groups than in homogeneous groups.

Some studies showed that low-achieving students who are assigned to courses according to their ability even learn more in heterogeneous groups (Burris et al. 2007; Marzano et al. 2001). While the use of heterogeneous groups for low-achievers is generally not controversial, it could equally help high achievers. In fact, Webb et al. (1997) and Johnson and Johnson (1999) indicated that high-achieving students show equally strong learning outcomes in heterogeneous groups. Evidence of this includes research by Healy (2010) who suggested that low ability tends to do well in heterogeneous group as shown in table 1.2.

	Same-ability groups			Mixed-ability groups		
Tests	High	Intermediate	Low	High	Intermediate	Low
Differential test						
Mean	85	64	55	82	80*	78*
Standard Deviation	7.8	5.6	6.2	7.5	4.3	5.1
Number of Students	33	27	14	35	26	15
Common Test						
Mean	88	41	____@	85	65*	54
Standard Deviation	8.1	5.1	____	6.9	6.1	3.9
Number of Students	33	27	14	35	26	15

Table 1.2: Achievements (Means in Percentages) in Mathematics at the End of 8th Grade (Healy 2010)

Shown in table 1.3 below is another result of an experiment conducted in Linchevski and Kutscher (1998) which suggested that heterogeneous grouping benefits low ability student more than homogeneous grouping.

Tests	Same-ability groups			Mixed-ability groups		
	High	Intermediate	Low	High	Intermediate	Low
Differential test						
Mean	85	64	55	82	80*	78*
SD	7.8	5.6	6.2	7.5	4.3	5.1
n	33	27	14	35	26	15
Common test						
Mean	88	41	—[a]	85	65*	54
SD	8.1	5.1	—	6.9	6.1	3.9
n	33	27	14	35	26	15

Table 1.3: Mathematics Achievements (means in %) at the end of 8th grade (Linchevski & Kutscher 1998)

[Where high, intermediate and low represent high, intermediate and low ability students in both tables]

These and many more researchers have suggested that low-ability students do better in heterogeneous grouping. Though the high ability and average student are also affected by this grouping mode, it nevertheless often shows the most significant impact on the low-ability students.

1.2 Project Description

Building on the research illustrated above, a plan was laid to assess what effect heterogeneous grouping will have on the mathematics achievements of low-ability primary school students in a computer supported collaborative learning. The assessment took the form of an experiment where the students' formative and summative assessments were used as input into the newly developed collaborative learning environment application, the Math Learning Collaborator (MLC).

MLC is the application specifically built for the experiment, and have the analytic features required by the experiment. The students were separated into four groups (two heterogeneous groups, one homogeneous group and one separated group). Each group consists of four students. The heterogeneous groups consist of two high-ability and two low-ability students each. The homogeneous and separated groups consist of four low-ability students each. The students in both heterogeneous and homogeneous groups were meant to learn together in their respective groups. The students in the separated group learnt individually. Shown below in figure 1.1 is the experiment plan.

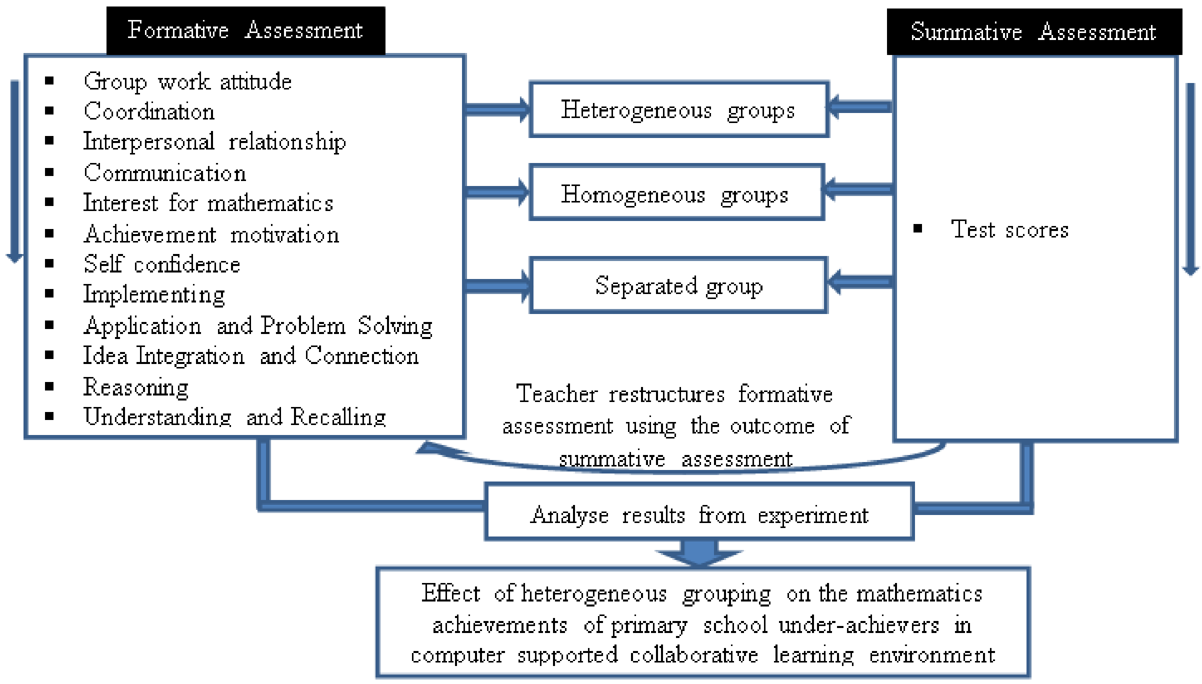

Figure 1.1: Experimental Plan Diagram. (Author)

Group 1	Heterogeneous group: two high-ability and two low-ability students working together
Group 2	Heterogeneous group: two high-ability and two low-ability students working together
Group 3	Homogeneous group: four low-ability students working together
Group 4	Separated group: four low-ability students working individually

Table 1.4: Group Arrangement. (Author)

Some of the attributes in figure 1.1 do not apply to the separated group because the students in this group learnt individually. The resolution of these attributes is shown in table 1.5.

GROUP	FORMATIVE ASSESSMENT ATTRIBUTE
Heterogeneous and Homogeneous Groups	Group work attitude, coordination, interpersonal relationship, communication, interest for mathematics, achievement motivation, self-confidence, implementing, application and problem solving, idea integration and connection, reasoning and understanding and recalling
Separated Group	Interest for mathematics, achievement motivation, self-confidence, implementing, application and problem solving, idea integration and connection, reasoning and understanding and recalling

Table 1.5: Formative Assessment Attribute Resolution Table. (Author)

Table 1.6 shows further resolution of assessment attributes related to different resources employed in the experiment.

RESOURCE TYPE	ASSESSMENT ATTRIBUTES
Device	Device Accuracy, Device Reliability, Versatility, Programmability, Device Communication, Device Usability and Performance
Artefact	Ease of use, Communication Capability, Meaningful Graphics, Text Readability, Effectiveness, Application Accuracy and Functionality
Teacher	Monitoring, Equity, Teacher's Reliability, Validity, Guidance, Feedback, Teacher's Communication and Teacher's Organization

Table 1.6: Additional Resource Attributes Resolution Table. (Author)

The results from the experiment (empirical data or evidence e.g. formative and summative assessment results) above were analysed using mathematical/statistical techniques e.g. mean, standard deviation, variance etc. to finally get a clear evidence of the effects as shown in figure 1.1. The difficulty of measuring those formative assessment results (qualities) was overcome by quantifying them as adopted from Bekele (2006).

In addition, some pre-tests were given to the students, which were used where necessary in the analysis in chapter six. In addition, the outcome from the analysis of the results was justified using the formative assessment results as will be discussed in chapter six of this research project. The assessment used a method of individual outcome of a collaborative process as adopted from the EDUCLAUSE journal, and is the process where the students (in group one to three) learn collaboratively but take tests individually.

Formative Assessment

This was adopted from Black and Williams (1998), and is the process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to help students improve their achievement of intended instructional outcomes. It provides insight on how much and how well the students are learning and not graded. It is continuous which implies that it is taken at varying intervals throughout a course to provide information and feedback that will help improve the quality of student learning and the quality of the course itself.

The formative assessment was employed in the experiment to enable the teacher move around the class during the mathematics learning session to know how each group is doing with their learning process by asking some descriptive questions and based on the feedback from the students, the teacher took some necessary actions e.g. showed them how to solve a particular problem, etc. The learning sessions involved the heterogeneous groups, the homogeneous group and the separated group as explained, and lasted for 30 minutes each, after which the summative assessment begins.

<u>Summative Assessment</u>

This was adopted from Angelo and Cross (1993), and is the process used after instruction or teaching to measure students' achievement, which provides evidence of students' competence, or programme effectiveness. It might be taken by students at the end of a class lesson units (daily, weekly, fortnightly etc.), semester (quarterly) etc. to demonstrate the sum of what they have or have not learnt. In order words, it is a summary of the development of a learner after a fix period of time after which the learners sits and write tests prepared by the teacher. The teacher marks these tests and gives scores to the students. The aim of these tests is to summarize the learning up to that point. In order words, it is the evaluation of students achievements via grades, scores etc.

The summative assessment was employed in this experiment in order to enable the teacher to send the tests from her computer to the students' computing devices. The student took the tests individually. The tests were automatically marked when the student submitted them. The students viewed their results after submission and took necessary and proactive actions. The teacher used these test results for diagnostic assessment to identify any weaknesses and then build on that using formative assessment.

1.3 Research Questions

With this in mind, the following six research questions were addressed in this research. Each of these research questions has a set of two hypotheses of which one was meant to be verified in order to address the question.

Research Question 1 - Using the MLC, will there be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth class primary school students placed in the homogeneous group for the topics taken?

- Null hypothesis 1 - *Using the MCL, there will be no significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*
- Alternative Hypothesis 1 - *Using the MCL, there will be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*

Research Question 2 - Using the MLC, will there be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken?

- Null hypothesis 2 - *Using the MLC, there will be no significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*
- Alternative hypothesis 2 - *Using the MLC, there will be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*

Research Question 3 - Using the MLC, will there be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth class primary school student placed in the homogeneous group for the topics taken?

- Null hypothesis 3 - *Using the MCL, there will be no significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the homogeneous group for the topics taken.*
- Alternative Hypothesis 3 - *Using the MCL, there will be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the homogeneous group for the topics taken.*

Research Question 4 - Using the MLC, will there be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken?

- Null hypothesis 4 - *Using the MCL, there will be no significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken.*
- Alternative Hypothesis 4 - *Using the MCL, there will be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken.*

Research Question 5 - Using the MLC, will there be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken?

- Null hypothesis 5 - *Using the MLC, there will be no significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken.*
- Alternative hypothesis 5 - *Using the MLC, there will be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken.*

Research Question 6 - Using the MLC, will there be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth class primary school student placed in the separated group for the topics taken?

- Null hypothesis 6 - *Using the MCL, there will be no significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the separated group for the topics taken.*
- Alternative Hypothesis 6 - *Using the MCL, there will be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the separated group for the topics taken.*

The dependent variable is defined here as the post-tests and pre-tests scores of the fourth-class primary school students. The independent variables are the three methods of arrangement (heterogeneous group, homogeneous group and separated group) and the constant variable is the amount of class time each student spent in class during the experiment. The heterogeneous learning groups are the experimental or treatment groups, and the homogeneous group and separated group constitute the control group. The research question is addressed in chapter six of this research by verifying either the null or the alternative hypothesis accompanying each question via empirical analysis.

With this in mind, some combinations of students may have advantages over others in terms of students' learning. Most empirical research on group composition has focused on the mixture of achievement levels, and it is widely believed that heterogeneous groups benefit lower-achieving students by giving them access to the intellectual resources of higher-achievers, and according to Webb et al. (1997), low-achieving students learn more in heterogeneous than in homogeneous groups. Burris et al. (2007) and Marzano et al. (2001) argue that low-ability students even learn more in heterogeneous groups. Webb et al. (1997) and Johnson and Johnson (1999) indicated that high-achieving students show equally strong learning outcomes in heterogeneous groups.

1.4 Research Objectives

The followings are the research objectives of this project:

- To examine the education philosophy and e-learning focusing on the nature of computer-aided learning and heterogeneous grouping world-wide (including Ireland).
- To investigate the current views and research conducted on heterogeneous grouping on computer supported collaborative learning environment.
- To develop an experiment to determine how this mode of grouping affects the mathematics achievement of the low-ability primary school students in a computer supported collaborative learning environment.
- To document and evaluate the findings from the experiment.
- To suggest whether primary schools that have computing devices will employ this mode of grouping more in their mathematics lessons based on the evaluation results.
- To make recommendations for any future research in this area.

1.5 Research Methodology

The primary source of information for this research came directly from participants involved in this research (the sixteen 4th Class Presentation Primary School Students and the teacher) making it seventeen participants. The following methods were used in collecting the primary data.

Quantitative

The students' summative assessment results were used to gather the quantitative data for this research.

Qualitative

- Questionnaires: Survey questionnaires were used in gathering part of the qualitative data for this research. The questions used in these questionnaires where all closed-ended questions, and limited to five options each, in which one option can be chosen. This made it easier for the students to fill the questionnaires. In addition, a comment field was left at the end of each questionnaire for any other opinion the participants may have, which was not included in the questions. These comment fields made it more open-ended question in which the participants (respondents) was meant to show more reflection of their opinions on the experiment.
- Interview: Interviews or field surveys were used in gathering part of the qualitative data for this research. The interviews were all open-ended, and as a result, were considered very useful for qualitative part of this research.

All the questionnaires and summative assessment results were stored electronically in the database thereby eliminating the cost for papers, ink etc.

1.6 Resources

A number of resources were used for the successful completion of this research project. Table 1.7 lists the resources which were used during the course of conducting the research project.

TECHNICAL RESOURCES	
Devices	Seventeen laptops
Artefact	Math Learning Collaborator
Network	WIFI
DBMS	MySQL Server 5.0
Platform	Microsoft Windows
Libraries	Deploy, Ibatis Common, Java Web Start, JavaFX Runtime, Plugin, Standard Library (JRE System Library) and MySQL Connector
CASE Tools	IBM Software Architect Standard Edition, NetBeans IDE, Erwin Data Modeller, Oracle Data Modeller, Nero Recode and Aunsoft Video Converter.
NON-TECHNICAL RESOURCES	
Primary School Access	Sixteen 4^{th}-Class Presentation Primary School students and a teacher
Access to Electronic Libraries	DIT Electronic Library, Academic Search Complete, IEEE Xplore Digital Library, ACM Digital Library, Science Direct and Web of Knowledge
Search Engines	Google, Google Scholar, Scirus, Science Accelerator, ScienceResearch, SciSeek, WorldWideScience, Zanran, Summon

Table 1.7: Resource List Table. (Author)

1.7 Scope, Limitations, Assumptions and Constraint

<u>Research Scope</u>

This research was conducted at Presentation Primary School, Warrenmount, Blackpitts, Dublin 8. The research lasted for three weeks beginning from 10 June 2013 and ending on 28 June 2013. There were seventeen participants involved. These participants consists of sixteen 4^{th}-class Presentation Primary School Students and a teacher. The research involved nine topics selected from three strand units that were under two strands.

<u>Product Scope</u>

- Math Learning Collaborator will allow teacher to be able to register, teach and test primary school students in groups.
- It will allow students to learn in four groups.

- The students will be able to learn with members of their groups if they belong to group 1 to 3, but individually if they belong to group 4.
- It will allow students to be able to take test individually regardless of their groups.
- It will allow the teacher and the students to see the results.
- It will allow students and the teacher to rate themselves, their devices and the application itself.
- In addition, it will allow students to be able to rate the teacher and vice versa.

Research Limitations

- This research did not consider contextual variables related to the composition of group with respect to any sociological, psychological and preferential variables e.g. team member gender, personal preferences, and level of team member familiarity or age.
- The research only focused on sixteen primary school students.
- This research did not include video-interviews of primary school participants in order not to violate data protection rights of these participants, and especially the child safety rights of the students.

Research Assumptions

- The research writer will ensure all necessary resources are available as needed to complete the project tasks and objectives.
- Failure to identify changes to draft deliverables within the time specified in the project timeline will results in project delays.
- The research writer will adhere to the communication plan.
- The research writer will ensure the existence of the computer infrastructure that can support the research application (Math Learning Collaborator) in the primary school used for the research.
- All the project participants (Presentation primary school students and teacher) will if necessary abide by guidelines identified within the plan.
- The project plan may change as new information and issues are revealed.

Research Constraint

The constraints for this project include a timeframe of 3 months and a team of research writers made up of one member.

1.8 Dissertation Outline

- Chapters two and three examine, in detail, a range of research literature focussing on three major areas of this project which are learning theories, instructional design and e-learning.
- Chapter four deals with the development of the MLC application used for this research, and how its design conformed to learning theories, instructional design and e-learning.
- Chapter five deals with the database used for this research, and how it stores the key information that allows the exploration of the key research questions.
- Chapter six details the experiment conducted for this research and an evaluation of the results from the experiment in detail.
- Chapter seven concludes the research by stating its contribution to the body of knowledge, limitations of the research, suggestions of future work and research.

2. Educational Philosophy

2.1 Introduction

This chapter reviews some of the main theories of learning, focusing on Behaviourism, Cognitivism, and Constructivism. In behaviourism, a change in a child's behaviour manifests learning. In cognitivism, a child generates knowledge via interaction and self-cognition development. In constructivism, a child constructs knowledge based on her mental activity. The chapter then looks into the instruction design to understand and explain how instructional design that results in efficient, effective and appealing acquisition of knowledge and skill in children learning and teaching are created. The chapter finishes by discussing the ICARE model, which provides a way of structuring and organizing a course or learning content.

2.2 A Review of Learning Theories

Although there are many different approaches to learning, there are three basic types of learning theory: Behaviourism, Cognitivism and Constructivism.

2.2.1 Behaviourism

Watson (1913) coined the term "behaviourism". He believed that theorizing thoughts, intentions or other subjective experiences was unscientific and insisted that psychology must focus on measurable behaviours (Good & Brophy 1990). Behaviourism is a theory that rests on three basic assumptions: firstly, a change in behaviour demonstrates learning; secondly, the environment influences the behaviour; and thirdly, the learning process can be explained via Principles of Contiguity and Reinforcement. In behaviourism, learning is the gaining of new behaviour through conditioning (Good & Brophy 1990).

For the child to acquire knowledge in this type of learning, the instructor must use explanation to pass the knowledge, and then monitor, judge, and alter behavioural changes of the child to suit the learning process. According to Watson (1913), this kind of basic learning is a conditioned reaction or rote learning of facts, assertions, rules, laws, and terminology. In order to get the correct response, the child's senses must be stimulated. The primary focus of children's intelligence development in this learning is the visual and bodily intelligence. Its purpose in education is to aid a child develop initial schema by gaining knowledge from an instructor through use of his senses with the goal of acquiring the factual knowledge, skill development, and training.

Thorndike (1932) specified three conditions that maximises child learning in constructivism, which are called Thorndike's principles of learning. These learning principles are:

- **The Law of Effect**: It states that the likely recurrence of a response is generally governed by its consequence or effect generally in the form of reward or punishment.
- **The Law of Recency**: It states that the most recent response is likely to govern the recurrence.
- **The Law of Exercise**: It states that stimulus-response associations are strengthened through repetition.

2.2.2 Cognitivism

Cognitivism is based on the premise that humans, especially children, generate knowledge via interaction and self-cognition development such as the mental processes to recognize, recall, analyse, reflect, apply, create, understand, and evaluate (Mandler 2002). It concerns what a learner knows and how to process information efficiently. The cognitivist paradigm essentially argues that the "black box" of the mind should be opened and understood. The learner is viewed as an information processor (like a computer).

Cognitivism has its roots in Gestalt psychology, and the word "gestalt" is a German word meaning "essence or shape of an entity's complete form". "The whole is greater than the sum of the parts" is often used when explaining Gestalt theory. Gestaltists see objects as perceived within an environment according to all of their elements taken together as a global construct (Boeree 2000).

One of the founders of gestalt, Koffka, believed that a lot of learning occurs by imitation. According to Koffka, the highest type of learning is "ideational learning", which makes use of language (King et al. 2009).

2.2.3 Constructivism

Constructivism as a learning theory is a philosophy, which aids students' logical and conceptual growth. It is based on the premise that the child constructs knowledge based on mental activity. There are four major areas in constructivism, which are:

- Cognitive Constructivism
- Co-constructivism
- Situated Constructivism
- Radical Constructivism

There are some overlaps in these areas as shown in figure 2.4.

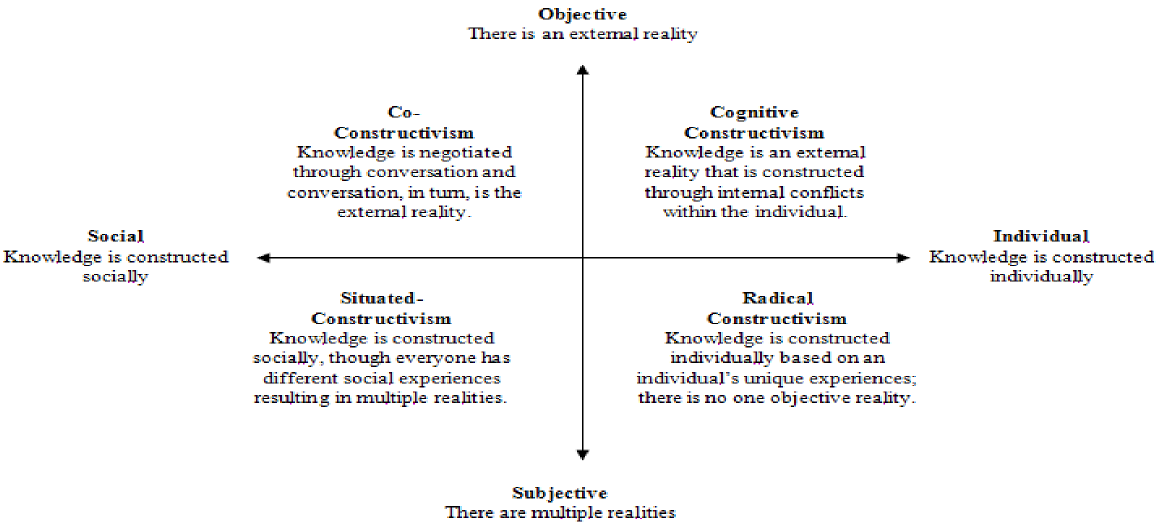

Figure 2.1: Major Areas of Constructivism (Kanuka & Anderson 1999)

<u>Cognitive Constructivism</u>

Cognitive Constructivism emphasises two points:

- *Learning is an active process* - According to Bruner (1966), the children take responsibility for their learning, and they might begin from what they already know, explore other areas and even draw conclusions. They gain knowledge and make new connections by progressing through various stages of the process. The instructor's role is to guide, facilitate and provide a variety of appropriate opportunities for children to engage in their own learning, and to encourage them continually to construct meaning and make connections for themselves.
- *Learning should be whole, authentic, and "real"* - Piaget (1962) showed that meaning is constructed as children interact in meaningful ways with the world around them. Thus, making less emphasis on isolated "skill" exercises that try to teach something like long division or end of sentence punctuation. Students still learn these things in cognitive

constructivist classrooms, but they are more likely to learn them if they are engaged in meaningful activities.

Co-constructivism

The foundation of this theory came from the statement made by Vygotsky (1962), one of the founders of co-constructivism that anything a child can do today in cooperation, he will be able to do on his own tomorrow. According to Vygotsky (1962), children develop their own knowledge and this development can be separated from the social context. Vygotsky (1962) went on to state that prior conceptions and new concept are interwoven during the learning, and language plays a central role in the child's mental development. According to Gillis and Galenza (2008), co-constructivism embraces the necessity of children to solve problems using conversation. In other words, it allows children to share meanings and knowledge via interaction.

Situated Constructivism

In situated constructivism also called situated cognition, learning is a social participation. Cognition takes place in the social environment, and minds are not separate from the culture. Knowledge is distributed across the cultural environment e.g., tools, books, and communities etc., and knowledge is effective participation in socially valued endeavours.

Radical Constructivism

Radical constructivism is an unconventional approach to the problem of knowledge and knowing. It starts from the assumption that knowledge, no matter how it is defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows based on his or her own experience. What people make of experience constitutes the only world they consciously live in. It can be sorted into many kinds, such as things, self, others etc., but all kinds of experience are essentially subjective.

Piaget (1962) looked at constructivism in education focusing on four factors, which are:

- **Schemas** – A schema (or category of knowledge) describes both the mental and physical actions involved in understanding and knowing.
- **Assimilation** – New information is easily incorporated into children's previously existing schemas.

- **Accommodation** – The process of changing or altering children's existing schemas in light of new information.
- **Equilibration** – This is the balance between assimilation and accommodation.

Vygotsky (1962) constructed a framework called a Zone of Proximal Development (ZPD) and according to this Vygotsky's Zone of Proximal Development, there is a difference between what a learner can do without help and what he or she can do with help. This is shown in figure 2.2.

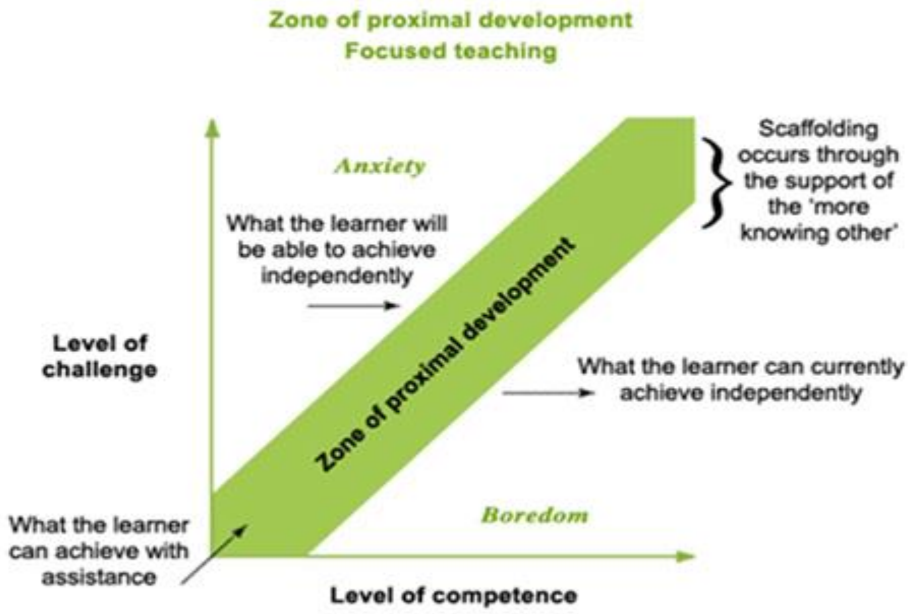

Figure 2.2: Zone of Proximal Development (Hill & Crevola 2006)

As shown in figure 2.2, the lower limit of ZPD is the level of skill reached by the child working independently. The upper limit is the level of additional responsibility the child can accept with the assistance of an able instructor. Scaffolding is changing the level of support. Over the course of a teaching session, a more-skilled person adjusts the amount of guidance to fit the child's current performance.

Dewey (1959) developed the idea that there is a coordination by which the stimulation is enriched by the results of previous experiences. He stated that reflection, as a meaning-making process, transitions the learner from one experience to the next with deeper understanding of its connections to other experiences and ideas. He stated that it is the thread that makes continuity of learning possible, and insures the progress of the individual, and, ultimately, society and has a means to essentially moral ends. This is shown in the experiential learning model in figure 2.3.

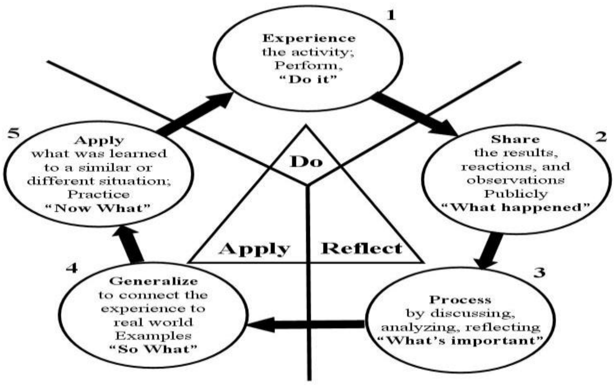

Figure 2.3: Experiential Learning Model (Pfeiffer & Jones 1975)

Montessori (1967) viewed constructivism as the relinquishing of freedom of environment to a child, prepared with materials designed for the child self-directed learning activity to the child. Montessori (1967) proposed three-period lesson. **Period 1** consists of providing the child with the name of the material. **Period 2** is to help the child recognize the different objects. After spending some time in the second period, the child may move on to period 3. **Period 3** involves checking to see if the child not only recognizes the name of the material, but also is able to tell what it is.

Montessori (1967) went ahead to define four stages or planes of development, which are:

1. **The First Plane** - This is for children between 0 to 6 years of age. This involves basic personality formation and learning through physical senses. During this plane, children experience sensitive periods for acquiring language and developing basic mental order.
2. **The Second Plane -** It is for children between 6 - 12 years, and involves learning through abstract reasoning, developing through a sensitivity for imagination and social interaction with others.
3. **The Third Plane** - This for the children between 12 – 18 year, and is the period of adolescent growth, involving the significant biological changes of puberty, moving towards learning of the human personality, especially as related to experiences in the surrounding community.
4. **The Fourth Plane -** This is for adults over 18 years old, and involves a completion of all remaining development in the process of maturing in adult society.

2.3 Instructional Design

Instructional Design (also called Instructional Systems Design (ISD)) is the practice of creating instructional ideas or experiences that result in more efficient, effective and appealing acquisition of knowledge and skill (Merrill et al. 1996). The process consists of determining the current state and needs of the learner, defining the end goal of instruction, and creating some "intervention" to assist in the transition. The outcome of this instruction may be directly observable and scientifically measured or completely hidden and assumed (Merrill et al. 1996).

Lewin (1935) suggested three considerations when dealing with instructional design. These are:

- **Active Learning** - Instruction must be planned with a clear vision of what the students will do with the content presented Lewin (1935). It is critical that students interact with the instructional content and that activities be developed to promote and support open-ended, self-directed learning. Content should never be delivered for memorization, but instead for use as a tool in planned and sequenced activities Lewin (1935).
- **A Cohesive Approach** - Lewin (1935) wrote that a piecemeal approach to guiding learners to accept new ideas, attitudes, and behaviours is ineffective. Instead, a cohesive approach must be utilized to support changes in cognition, effect, and behaviour.
- **Impact of the Social Environment** - Lewin (1935) theorized that before changes in ideas, attitudes, and behaviour will occur, modifications in a learner's perception of social environment are essential. He also argued that it is easier to create change in a social context than individually.

Gagné (1985), who was involved in applying instructional theory to the design of computer-based learning, assumed that different types of learning exist, and that different instructional conditions are most likely to bring about these different types of learning. He stated that there are five categories of learning outcomes, which are:

- Verbal information
- Intellectual skills
- Cognitive strategies
- Motor skills
- Attitudes

Gagne (1985) went ahead to formulate one of the fundamental concepts in learning. These are called Gagne's Nine Events of Instruction as discussed in the next subsection.

2.3.1 Gagne's Nine Events of Instruction

The nine events of instruction are:

1. **Gain attention** - Stimulate students with novelty, uncertainty and surprise.
2. **Inform learners of objectives** - Inform students at the start of the course of the objectives to help them understand what they are to learn during the course.
3. **Stimulate recall of prior learning** - Help students make sense of new information by relating it to something they already know or something they have already experienced.
4. **Present the content** - Use strategies to present and cue lesson content to provide more effective and efficient instruction. Organize and chunk content in a meaningful way, and provide explanations after demonstrations.
5. **Provide learning guidance** – Advise the students of strategies to aid them in learning the content and of resources available.
6. **Elicit performance (practice)** - Eliciting performance provides an opportunity for learners to confirm their correct understanding, and the repetition further increases the likelihood of retention.
7. **Provide feedback** – Provide immediate feedback of students' performance to assess and facilitate learning. Guidance and answers provided at this stage are called formative feedback.
8. **Assess performance** – The students should take a final assessment. In order to evaluate the effectiveness of the instructional events, the teacher must test to see if the students have achieved the expected learning outcomes. The teacher should base the performance on previously stated objectives.
9. **Enhance retention and transfer to the job** - Effective education will have a "performance" focus. To help learners develop expertise, they must internalize new knowledge. Methods for helping learners internalize new knowledge include:
    - Paraphrasing content
    - Using metaphors
    - Generating examples
    - Creating concept maps or outlines
    - Creating job-aids, references, templates, or wizards

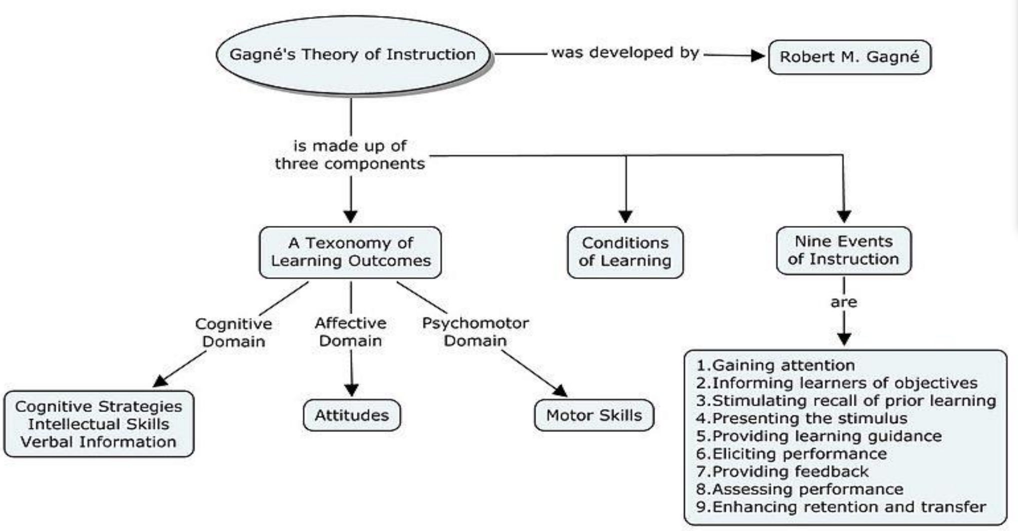

Figure 2.4: Structure of Gagne's Nine Events of Instruction (Driscoll 2004)

Another theory in instructional design that needs mentioning is Information Processing Theory, which is discussed in the next subsection.

2.3.2 Information Processing Theory

Information processing theory lays emphasis on a child's memory components in enhancing the child's learning, and ways in which the child's memory analyses and retains an amount of information (Suthers 2002). There have been some models of information processing, but the most widely used model is the stage theory model, which is based on the work of Atkinson and Shiffrin (1968). This model views learning and memory as discontinuous and multi-staged (Atkinson & Shiffrin 1968). The stage theory model recognizes three types or stages of memory: sensory memory, short-term or working memory, and long-term memory (Atkinson & Shiffrin 1968).

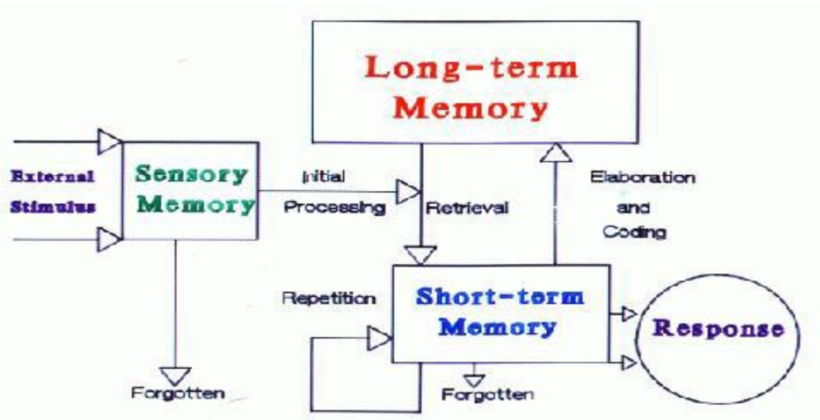

Figure 2.5: Stage Theory Model (Atkinson & Shiffrin 1968)

- Sensory Memory (SM) - Sensory memory is affiliated with the transduction of information into form the child memory can understand (Suthers 2002).
- Short-Term Memory (STM) - Short-term memory is affiliated with holding information in child's conscious awareness for a short period-of-time, and is the result of child's attenuation to an external stimulus, an internal thought, or both. The information might last around 20-30 seconds unless it is rehearsed, at which point it may be available for up to 20 minutes in the child's memory (Suthers 2002). According to Suthers, in order to retain information in the child's STM, the information must be organised and repeated.
- Long Term Memory (LTM) - LTM is the information, which has been isolated from child conscious awareness, but is retrievable after long periods of time (Suthers 2002). Suggestions were made by Suthers (2012) that visual images should be used in reinforcing and recalling information for children, and also the connections between new and prior information promotes child's learning.

With this in mind, children also need an iterative problem-solving strategy. The TOTE model is a good model for this strategy as discussed in the next subsection.

2.3.3 TOTE Model in Information Processing Theory

The TOTE, standing for "Test - Operate - Test - Exit", is an iterative problem solving strategy based on feedback loops. The generic TOTE structure is shown in table 2.1:

Test	Obtain some representation of the problem state
Operate	Instructor intervenes in some way
Test again	Check if the desired result has been achieved. If it has not, loop back to operate
Exit	Problem solved

Table 2.1: TOTE Structure (Miller et al. 1960)

The following principles are central to the concept of the TOTE unit according to (Miller et al.1960):

- Planning consisting of TOTE units is essential in cognitive process.
- Control of behaviour exposes a set of chunks and TOTE units.

However, one weakness of this model is that it is fixed and static. There is no dynamic in it. A child's act on the environment is always according to the same plan. This creates an infinite loop.

With this in mind, children should be taught by organising the content from simple-to-complex order (Reigeluth 1999) as discussed in the elaboration theory in the next subsection.

2.3.4 Elaboration Theory

Elaboration theory is an instructional design theory that argues that content to be learned should be organized from simple to complex order while providing a meaningful context in which subsequent ideas can be integrated. The paradigm shift from teacher-centric instruction to learner-centred instruction has caused “new needs for ways to sequence instruction” (Reigeluth 1999). According to Reigeluth (1999), elaboration theory is an instructional design model that aims to help select and sequence content in a way that will optimize attainment of learning goals in children. Proponents feel the use of motivators, analogies, summaries and syntheses leads to effective learning. While the theory does not address primarily affective content, it is intended for medium to complex kinds of cognitive and psychomotor learning.

Reigeluth (1999) devised eight steps in elaboration theory, which are:

1. **Organizing Course Structure:** Single organisation for complete course in child learning.
2. **Simple to complex:** Start with simplest ideas, in the first lesson, and then add elaborations in subsequent lessons.
3. **Within-lesson sequence:** General to detailed, simple to complex, abstract to concrete.
4. **Summarizers:** Content reviews presented in rule-example-practice format.
5. **Synthesizers:** Presentation devices that help the child integrate content elements into a meaningful whole and assimilate them into prior knowledge.
6. **Analogies:** Relate the content to child’s' prior knowledge, use multiple analogies, especially with a highly divergent group of learners.
7. **Cognitive strategies:** Variety of cues - pictures, diagrams, mnemonics, etc. - can trigger cognitive strategies needed for processing of material.
8. **Learner control:** Children are encouraged to exercise control over both content and instructional strategy. Clear labelling and separation of strategy components facilitate effective learner control of those components.

Most of the instructions in teaching and learning in child education are problem-centred, which leads to the five principles of instructions by Merrill (1994) as discussed in the next subsection.

2.3.5 Merrill's Five Principles of Instructions

Merrill (1994) proposed first five principles for problem-centred instructions. These allows for proper teaching and learning in children's education. These principles are:

1. Learning is promoted when learners are engaged in solving real-world problems.
2. Learning is promoted when existing knowledge is activated as a foundation for new knowledge.
3. Learning is promoted when new knowledge is demonstrated to the learner.
4. Learning is promoted when new knowledge is applied by the learner.
5. Learning is promoted when new knowledge is integrated into the learner's world.

Merrill (1983) device a component display theory that classifies child's learning into content and performance as discussed in the next subsection.

2.3.6 Merrill's Component Display Theory

According to Merrill (1983), Component Display Theory (CDT) classifies learning along two dimensions: content (facts, concepts, procedures, and principles) and performance (remembering, using, and generalities). The theory specifies four primary presentation forms: rules (expository presentation of a generality), examples (expository presentation of instances), recall (inquisitory generality) and practice (inquisitory instance). Secondary presentation forms include prerequisites, objectives, helps, mnemonics and feedback.

Having discussed the instructional design, there is an important model abstracted from the instructional design practice for structuring and organising the course content for learning (especially in children learning). It is called ICARE model, and is discussed in the next section.

2.4 The ICARE Model

According to Salyers (2006), ICARE has potential as one possible means for structuring and organizing course content. According to (Hoffman & Ritchie 1998), the model is distilled from basic instructional design practice, and adapting variety of systems to what seemed to be particularly useful components for e-learning course design and development.

PHASE	DESCRIPTION
Introduction	This phase consists of the introduction to the unit of instruction including: Context, objectives, prerequisites, required study time, equipment required, essential reading materials
Connect or content	Almost all contents will reside in this section.
Apply all activities	Exercises, questions, etc. are implemented in this phase
Reflect	This phase provides an opportunity for learners to reflect on their acquired knowledge and articulate their experience. This section may include topics for discussion, a learning journal/log, and a self-test, formative and summative assessment.
Extend	An amalgamation of all the previous phases, which offers materials, and learning opportunities which can be remedial, supplemental, or advanced, depending on learner performance.

Table 2.2: ICARE Model. (Hoffman & Ritchie 1998)

2.5 Conclusions

Three basic learning theories discussed in this chapter aid in children's education. These three basic theories (behaviourism, cognitivism and constructivism) were proposed to ensure both teachers and students gain from teaching and learning. In addition, it explained how instructional ideas that result in efficient, effective and appealing acquisition of knowledge and skill in children learning and teaching are created by looking into the instructional design. Finally, the means of organizing and structuring the course or learning content called ICARE was discussed.

E-Learning is a relatively recent addition to the broad set of teaching approaches that have been developed since the first schools were founded over a thousand years ago. This is discussed in the next chapter.

3. E-Learning

3.1 Introduction

E-Learning (as the name suggests) refers to the learning that employs Information and Communication Technologies (ICT) in education. It might be used in conjunction with face-to-face learning (blended learning), and might be either synchronous, asynchronous or a combination of both. According to Tavangarian et al. (2004), it can take several forms, such as m-learning, virtual learning environments, blended learning, and computer aided learning.

With this in mind, this chapter looks at a brief history of eLearning, and the challenges and criticisms of eLearning. It then looks at computer-aided learning, virtual learning environments and blended learning approaches. It then looks at the use of these e-learning systems for teaching mathematics collaboratively in primary school education, and the GUI consideration factors when designing those systems. It finally looks at the heterogeneous grouping of students in these e-learning environments.

3.2 History of E-Learning

E-Learning is a relatively recent addition to the broad set of teaching approaches that have been developed since the first schools were founded over a thousand years ago (Holmes & Gardner 2006). The first real instance of eLearning can probably be dated to 1924 when American psychology professor Sidney Pressey, developed his "Testing Machine" (sometimes called the "Teaching Machine"). This machine presented students with multi-choice questions that allowed them to choose their answer by pressing the appropriate button, and this would be recorded on a sheet of paper stored within the machine (Holmes & Gardner 2006).

When computers became available to academic institutes in the early 1960s, educators began to employ them not only for record keeping but also for teaching (Fernández et al. 2006). One of the earliest proponents of this approach, an American education philosopher, Patrick Suppes, argued that computers could provide the one-to-one tuition that Benjamin Bloom demonstrated could improve student attainment by two standard deviations i.e. moving a student from achieving 50% to 98% (Fernández et al. 2006). Suppes founded the Computer

Curriculum Corporation in 1967, which developed computer systems to teach elementary mathematics (Fernández et al. 2006).

With the development of personal computers in the 1980s and the World-Wide Web in the 1990s, it became possible for educational institutes to harness fully the power of e-learning (Weiss et al. 2006). During the 1980s, single modules were first delivered online and then entire programmes were online, and by the 1990s Virtual Learning Environments were being developed to provide tools to aid teachers in the development and management of their courseware (Weiss et al. 2006). It is significant to note that there have been many challenges and criticisms of e-learning. Some of these challenges and criticisms are discussed in the next section.

3.3 Challenges and Criticisms of E-Learning

As the number of e-learning courses grows in institutions, there is a need to increase the number of students and teachers who have awareness of eLearning. Knowledge is normally conveyed via text, audio and/or video. This creates challenges that the students and teachers or instructors will have to overcome. In addition, as long as eLearning has been around, it has been criticised by some people who question its authenticity, viability, and quality.

3.3.1 Challenges of E-Learning

In order to look at challenges of eLearning, several areas and their factors need consideration. These areas are the instructors, the students, the technology itself and the e-learning course. There are other areas, but these are the most prominent ones that need consideration when looking into challenges in eLearning. These areas with their challenging factors are shown in table 3.1.

AREAS	CHALLENGING FACTORS
Instructors	Adaptation, e-learning time requirement, technical issues, computer experience, new teaching style confidence, motivation and commitment
Students	Computer experience and confidence, academic confidence, learning style, age, technical problems and time management
Technology	Resource availability, software and GUI design, cost and connection bandwidth.
Course	Curriculum design, pedagogical model and localization of content

Table 3.1: Challenges of E-Learning. Adopted from EDUCAUSE (2003)

As shown in table 3.1, the instructors and students face some challenges in using eLearning as the mode of teaching.

3.3.1.1 Instructor's Challenging Factors

Adaptation: One of the factors challenging eLearning is how instructors should adapt to a new e-learning environment when there is a change to an existing e-learning environment. Part of this requires a knowledge of how to take common classroom practices and plug them into the established structure of the software. This depends on other factors such as technology confidence, computer experience, motivation and commitment. In order to overcome adaptation challenge, the instructors need to improve their commitment, motivation experience and confidence on e-learning technologies.

E-learning Time Requirement: The amount of time teachers spend in order to develop and maintain an e-learning course relative to the traditional classroom course is overwhelming (EDUCAUSE 2003). In order to overcome this issue, as suggested by (EDUCAUSE 2003), the teachers have to:

- Rethink and restructure e-learning classes
- Need technical and pedagogical training
- Use less technologically sophisticated tools

Technical Issues: The lack of course prototypes and software standards, and technical limitations of course management software raise a challenge to the teacher. Many prototypes are developed on different platforms, which might lead to portability issues. This can be resolved by using only one platform to deliver these software solutions. Some technical issues however, happens accidentally. In this case, the teacher should have backups of the class course materials in case any of those issues arise. In addition, much of these technical issues can be overcome by alerting the supports.

Computer Experience: Lack of necessary computer experience by the teacher raises an issue in an e-learning environment. The teacher should be trained in her area of use to overcome this issue.

New Teaching Style Confidence: Lack of teaching style poses a challenge to a teacher in an eLearning environment. Overcoming this issue requires the teacher to be able to adapt his or her teaching style to technology changes, and be confident in it.

Motivation and Commitment: Lack of motivation and commitment on e-learning technologies poses an issue to the teacher. In order to overcome this issue, the teacher has to be motivated and committed on the e-learning environment and technologies.

3.3.1.2 Student's Challenging Factors

Computer Experience and Confidence: Lack of computer experience and confidence poses a challenge to the student. If a student does not know how to use the technology, it does mean the student might not get sufficient knowledge from his or her learning. In order to overcome this issue, students need to be trained on how to use the technology to learn. In addition, they should have confidence on the technology they are using.

Academic Confidence: Lack of academic confidence poses a challenge to a student in an e-learning environment. A student who does not have any confidence in his or her academics might have this psychologically affecting his or her eLearning experience. This can be overcome by improving the student academic confidence via academic advices etc.

Learning Style: Lack of learning style poses a challenge to a student in an e-learning environment. Overcoming this requires the student to be able to adapt his or her learning style to technology changes, and be confident in it with the help of the instructor.

Age: Age of the student in an e-learning environment can be a hindering factor to learning. For example, if a kindergarten student is given an iPad to use for his or her lesson it will look awkward to the student, and the student probably sees it as a playing toy instead of its intended purpose and even start hitting it against all kinds of objects in a worst-case scenario. This can be overcome by letting the children use e-learning resources according to their age.

Technical Problems: The lack of course prototypes, software standards and technical limitations of course management software raise a challenge to the student. Many prototypes are developed on different platforms, which might lead to portability issues. These can be resolved by using only one platform to deliver these software solutions to the students. In addition, much of these technical issues can be overcome by alerting the supports.

Time Management: Time management can have a huge impact on the student performance in an e-learning environment. Students should be given classes on time management skills.

3.3.1.3 Technology

Access: Lack of availability of e-learning resource poses an issue to the students and teachers. Students in an e-learning environment who do not have access to the resource cannot practically learn adequately, and teachers cannot teach. To overcome this, there should be availability of resource at any time to all the students and teachers.

Software and GUI Design: Poor software and GUI design pose a challenge in an e-learning environment. Some failures of e-learning systems are lack of good design. To overcome this, proper design methodology should be used in the development of the e-learning software.

Cost: This area is one of the most challenges facing eLearning in any learning environment. Cost, be it labour cost, installation cost, production cost, maintenance cost etc. can lead to any e-learning project being abandoned. Even if the e-learning project is completed and working, it might not necessarily meet the user demands, and worst still cannot be maintained appropriately. This can be overcome by employing cost management skills to meet up with the cost of e-learning technologies.

Connection Bandwidth: Poor connection bandwidth poses an issue in an e-learning environment. If the connection bandwidth is low, delivering learning resources will be slow and time-consuming. To overcome this, the need for reasonable bandwidth is necessary.

3.3.1.4 Course

Curriculum Design: Academic curriculum not designed to meet e-learning technologies raises an issue. For example, if an e-learning technology does not include plugins for a particular feature then designing curriculum that uses that feature is an issue. This can be avoided by a design curriculum that meets the e-learning requirements.

Pedagogical Model: Poor knowledge management is also a challenge in an e-learning environment. For example, presenting a material without appropriate explanation, analogies etc. can lead to student not assimilating the knowledge appropriately. This can be overcome if the instructor employs pedagogical content knowledge to teach the students.

Localization of content: Poorly localised content poses a challenge to students and teachers. For example, handling English learning notes in a French school will create a chaos. This can be overcome by translating those learning materials to the language of the intended students and teachers.

3.3.2 Criticisms of E-Learning

According to Deneen (2013), there are several criticisms of e-learning, but seven are described here. These criticisms are:

- The technology is unreliable
- It puts the teaching profession at risk
- Students are less likely to finish without a teacher overseeing their work
- It shelters students from the real world
- The technology is too expensive
- It does not provide real life experience
- It increases screen time, which is not good for the student eyes

3.4 Computer Aided Learning

Throughout the 1980s and 1990s, computers had been generally heralded as being an effective teaching and learning methodology (Christmann & Badgett 2000). Computer Aided Learning (CAL) involves the use of the computer system for a learning program designed to provide interactive instructions or learning services to pupils by allowing them to interact with lessons programmed into the system (Christmann & Badgett 2000). In other words, CAL is instruction or learning that involves the use of a computer system, including any of the hardware, software, network and telecommunication efforts for the primary use of learning. Nonetheless, the computer is able to keep a record and analysis of the outputs of all the learners, provide them with immediate knowledge of results, and enable teachers to maintain quality control (Christmann & Badgett 2000).

CAL has a rich history, and has emerged concurrently with the emergence of electronic computers (Coffland 1999). CAL, as an instructional or learning medium, facilitates teaching and learning, and the program may be localised on the learner's device in which the learner, in this context, manipulates the computer to suit his or her convenience in learning (Coffland 1999). On the other hand, the application may be networked so that the learners may use the computers to learn in groups. The teacher, in this context, can monitor learners' progress, and respond immediately, quietly and privately without disturbing the class where help, encouragement, or even discipline is needed. The feedback of any request may be given by sending it to the learner's device. Even suggestions, illustrative examples, on-line counselling etc. may be given. The teacher can broadcast a learner's display screen to every other workstation in the network when he or she is working on a program or problem that may be of interest to the rest of the class (Coffland 1999).

In CAL, the sequence of learning and the amount of time spent on learning tasks are determined by the performance of the learners themselves. Students are required to produce coursework and sit for examination. Measurement of the performance of the students is done both individually and in groups. This allows individual team member to be independently active and creative, and able to work coherently with the other members (Bakar 1998).

In a school with creative educational aims, the computer functions as a teaching assistant, frees the teacher of most of his or her strenuous duties, shares materials with students in the learning process, and allows learners to broaden their experience and stretches their minds. There has been a dramatic increase in the capabilities of computers along with reduced cost that has influenced an increase in the various forms of CAL (Brown 2001). This increase has been seen in education as well as in their disciplines (Passerini 2000).

With this in mind, another form of e-learning that needs discussion is virtual learning environment, which is discussed in the next section.

3.5 Virtual Learning Environments

A virtual learning environment (VLE), or learning platform, is an e-learning education system that models conventional in-person education by providing equivalent virtual access to classes, class content, tests, homework, grades, assessments, and other external resources such as academic or museum website links (Dillenbourg 2000). It is also a social space where students and teacher can interact through threaded discussions or chat. It typically uses web

2.0 tools for two-way interaction, and includes a content management system. There are many learning areas it is highly adopted, but one of this is collaborative learning or even distributed learning (Dillenbourg 2000).

Virtual learning environments are the basic components of contemporary eLearning, but can also be integrated with a physical learning environment, which may be referred to as "blended learning" (Dillenbourg 2000).

Virtual learning can take place synchronously or asynchronously. The former (synchronous) is more used in a real time active online learning, in which children or learners meet in "real time" and teachers conduct live classes in virtual classrooms. Students can communicate through chatting, video conferencing etc. Thus, students are able to talk with other students and the teacher, as well as collaborate with each other, answer questions, or pose questions. They can use the tools available through the application to virtually raise their hand, send messages, or answer questions on the screen given by the teacher or student presenter. The later (asynchronous) is more used in self-paced learning in which students are expected to complete lessons and assignments independently through the system.

According to (Guglielmo 2005), the functionality of VLE can be partitioned into five main areas. These are:

- **Information**: For the distribution of notices, documents and other data, such as announcements, regulations, syllabi and schedules to students.
- **Content**: For making available a wide range of electronic resources in a variety of media, ranging from learning materials and reading lists, through to video demonstrations and podcasts, plus hyperlinks to external content hosted anywhere on the Internet.
- **Communication**: Online tools augmenting face to face contact through facilities such as mailing lists, moderated discussion fora, messaging, and wikis.
- **Assessment**: Both formative and summative assessments can be supported in terms of tests, surveys, and assignments. Feedback can be provided using a variety of methods and media, including annotated scripts and video commentaries.
- **Management**: Perhaps of greatest overall organisational benefit, VLEs provide management tools operating at different levels. They can support the planning and delivery of courses across departments and schools covering course registration, student

monitoring, and the administration of marks. They provide a single point of online entry not only for the pedagogic purposes of teaching and learning, but also for administrative matters such as institutional audits.

With this in mind, VLE includes content management and open source tools, which need discussion.

3.5.1 Content Management System

Content Management Systems (CMS) refer to the system and processes whereby information is created, managed, published, and archived. Information (learning content) typically passes through this lifecycle for a finite period of time (Hannon Hill 2010). A content management system (CMS) provides the necessary infrastructure for multiple students to effectively contribute learning content and collaborate throughout these lifecycles (Hannon Hill 2010).
A CMS typically offers the following benefits to students, according to the journal (Hannon Hill 2010):

- Easy learning content creation and editing
- Access rights for security
- Structured workflow processes for learning content approvals
- Archival and versioning of learning content
- Templates for consistent output
- Learning content check-in/check-out services

3.5.2 Open Source Tools

Open source tools are tools used to support student learning in VLE. The tools and functionality available to the student and tutor vary from VLE to VLE. There are various kinds of open source tools in VLE, but two will be considered in this discussion, which are Bodington and COSE.

<u>Bodington</u>

Bodington was developed in University of Leeds. It has the following benefits to students and teachers (Bodington 2006):

- It is simple to use, both for navigation and for learning content creation.
- It has a fine-grained access control for all areas within the system that could be based upon existing institutional structures.

- Each area and resource within the system has a unique URL and thus could be referenced directly from external resource (or within the system itself).
- It has a default of making material open and does not mandate access based on course registration (particularly useful in a primary schools that promotes open access to material across the institution).
- It is written in Java, a robust programming language that could cope with the demands of an enterprise system.
- It has all the basic features primary schools need (upload/download, assessment, logbooks, discussion areas, etc.).
- Users (primary school students and teachers) can be given extra rights at any particular area of the system.
- It conforms to accessibility standards.
- It is free from product lock-in, which means it is all non-proprietary, and content can be moved in and out without third-party filters.
- It is free from monolithic structures. Thus, primary schools can start tools integration whenever they wish and bring in the best of breed products that they want to use, and not those dictated to them by other sectors.

COSE

COSE (Creation of Study Environments) is a server-based VLE, which supports the development and delivery of active learning content to learners working individually or in groups. It enables structured content to be prepared and managed, and the students to interact with it (COSE 2007). It is now an open source product. Its main goal is to provide a virtual learning environment aimed at the creation of study environments rather than just the delivery of "material" and to encourage development to take place in the context of coherent pedagogy, which promotes good practice. It, in addition, allows the creation of study environments, which can exploit material in a wide range of media and allows easy provision of mechanisms for support, feedback, collaboration and self-assessment without recourse by staff to skills such as scripting and mark-up languages (COSE 2007).

Benefits of COSE to Primary School Education (COSE 2007)

- COSE allows learning to be active and focused in the sense that it allows teachers to create learning opportunities which provide "something to do" along with resources (both inside and outside COSE), media objects, assessments, and references to traditional non-electronic resources.

- COSE enables learning to be learner centred
- COSE enables learning to be collaborative
- COSE allows Content to be reusable and stable
- COSE helps tutors to manage learning
- COSE makes submission of evidence of learning easy
- COSE provides feedback on learner activity
- COSE has low IT skills requirements
- COSE provides for central administration

Having discussed VLE’s content management system and open source, blended learning approaches that allow primary school students and teachers to be effectively engaged in learning and teaching needs discussed.

3.6 Blended Learning Approaches

Blended learning is a formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path or pace (Staker & Horn 2012). While still attending a “brick-and-mortar” school structure, face-to-face classroom methods are combined with computer-mediated activities (Strauss 2012). Proponents of blending learning cite the opportunity for data collection and customization of instruction and assessment as two major benefits of this approach (Caperton 2012). Schools with blended learning models may also choose to reallocate resources to boost student achievement outcomes (Anna 2011).

The two approaches of blended learning that will be discussed here are flipped classroom and m-learning.

3.6.1 Flipped Classroom

The flipped classroom, also called an inverted classroom, uses a strategy of teaching that engages a wide range of learners. Students are responsible to see the learning medium (material, video etc.) online to prepare for the academic work that will then be done during class time. During class time, students work on exercises independently or in groups. Teachers act as coach throughout the class period.

The purpose of flipping the classroom is to shift from passive to active learning to focus on the higher order thinking skills such as analysis, synthesis and evaluation (Bloom 1956). Students access key content individually (or in small groups) prior to class time and then meet face-to-face in larger group to explore content through active learning and engagement strategies. There are many permutations of what a flipped classroom will look like and depends on variables such as class size, resources, support and readiness to change.

In the flipped classroom, the roles and expectations of students and teachers change where:

- Students take more responsibility for their own learning and study core content either individually or in groups before class and then apply knowledge and skills to a range of activities using higher order thinking,
- Teaching 'one-to-many' focuses more on facilitation and moderation than lecturing, though lecturing is still important. Significant learning opportunities can be gained through facilitating active learning, engaging students, guiding learning, correcting misunderstandings and providing timely feedback using a variety of pedagogical strategies.
- There is a greater focus on concept exploration, meaning making and demonstration or application of knowledge in the face-to-face setting (see figure 3.1 below).

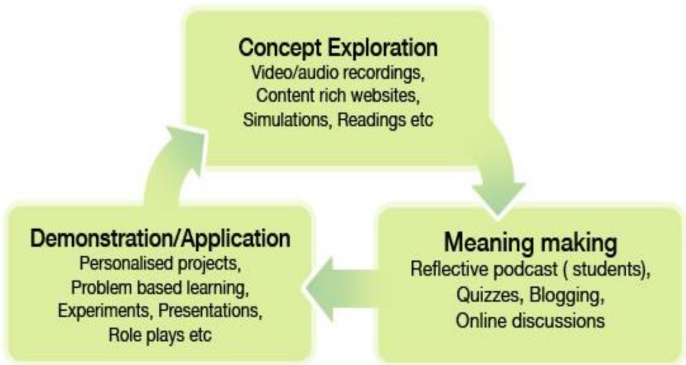

Figure 3.1: Learning Opportunities of Flipped Classroom (Gerstein 2013)

3.6.2 M-Learning

M-learning (Mobile learning) is defined as "learning across multiple contexts, through social and content interactions, using personal electronic devices” (Crompton 2013, p. 4). In other words, with the use of mobile devices, learners can learn anywhere and at any time (Crescente & Lee 2011).

M-learning technologies include handheld computers, MP3 players, notebooks, mobile phones and tablets. M-learning focuses on the mobility of the learner, interacting with portable technologies, and learning that reflects a focus on how society and its institutions can accommodate and support an increasingly mobile population. There is also a new direction in m-learning that gives the instructor more mobility and includes creation on the spot and in the field learning material that predominately uses smartphone with special software such as AHG Cloud Note. Thus, using mobile tools for creating learning aids and materials becomes an important part of informal learning.

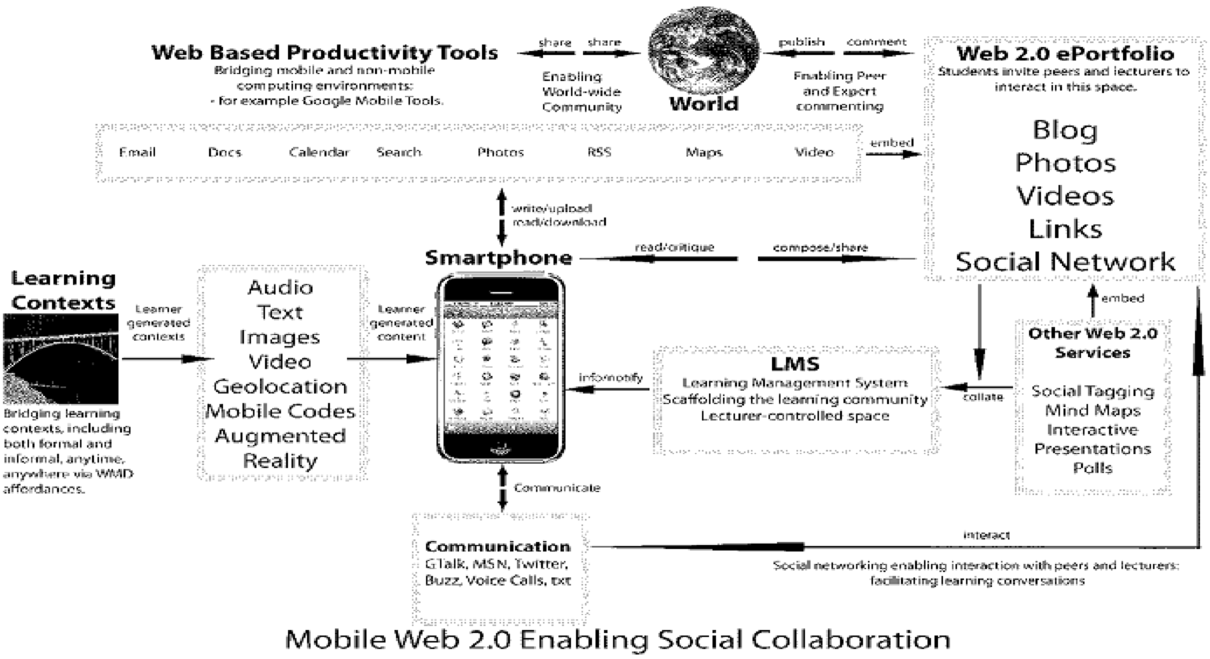

Figure 3.2: Mobile Web 2.0 Concept Map (Cochrane 2011)

Some benefits of m-learning in primary schools include but are not limited to:

- Making learning content universally accessible anytime and anywhere;
- Adapting to students' and teachers' needs;
- Increasing knowledge retention and saving time;
- Encouraging knowledge sharing and gathering;
- Creating best learning and teaching practices.

Having discussed all of the above, the e-learning systems that actually allow students to learn maths collaboratively are very important in any collaborative learning environment that uses e-learning as the mode of learning. This is discussed in the next section.

3.7 E-Learning Systems for Teaching/Learning Maths Collaboratively

For the e-learning system that allows teachers to teach and students to learn maths collaboratively, this section will focus on computer supported collaborative learning (CSCL). There have been many ways of teaching students mathematics. For this to be effective, students (in peer groups) need to impact knowledge on and learn from one another. This is where CSCL comes in.

Despite the apparent benefits, the efficacy of non-computer setting in peer group learning is often questioned. When students conduct the arithmetic task without technological tool, it is tedious and time-consuming (Noraini 2006). Such situations can be overcome by using computer programs that generate a quick and accurate graph of functions, observe the movement of graph using dragging and animation functions, which are hard to do with conventional static drawings.

The Sinclair (2005) model has been used by many researchers to study the peer intervention styles and strategies in the computer-supported collaborative learning using dynamic mathematics software, GeoGebra. This model was originally developed from the dynamical theory for the growth of mathematical understanding of Pirie and Kieren (1994) model. There are two extended elements of the Pirie and Kieren theory. They are folding back and teacher interventions. According to Tower (1998), the growth of students' mathematical understanding depended on the teacher's intervention in the classroom. Tower's work provided an initial framework for the analysis of Sinclair's study. Sinclair (2005) modified the work of Tower (1998) from teacher-student interventions to student-student interventions. Sinclair (2005) explored the interactions that took place between pairs of students in senior maths classes in a lab environment. In Sinclair's model, there are three intervention styles:

1. **Leading** – In which students go through a step-by-step explanation for their partner, checking understanding along the way.
2. **Showing and telling** – In which students tell their partners particular information, although it is sometimes inaccurate.
3. **Shepherding** – In which students help their partner understand.

Besides, there are eight intervention strategies in Sinclair's model:

1. **Checking** – Checking shared understanding.
2. **Reinforcing** – Repeating a theorem or finding for shared understanding.
3. **Inviting** – Playing to explore a new direction.
4. **Enculturating** – Correcting one another with respect to terminology although occasionally the correction is wrong.
5. **Blocking** – Keeping the pair focused or to cut off discussion.
6. **Modelling** – Using powerful effect by some students.
7. **Praising** – Praising themselves or giving a happy yelp.
8. **Rug pulling** – Not used by students.

Results of the Sinclair's research indicated that there was more than a sharing of information in students' interactions. They used interventions to correct mistakes, inform cut-off conversation, initiate play, and communicate their vision with their partner in order to develop mathematical understanding.

Having discussed all of the above, it is important to consider some factors when designing the GUI of an e-learning system (application). This is discussed in the next section.

3.8 Graphical User Interface (GUI) Design Factors

There are empirical studies that have identified basic psychological factors that one should consider in the design of good GUI of an e-learning system. The discussion will be narrowed down to three primary contributing human factors, which are the physical limits of visual acuity, the limits of absolute memory, and the Gestalt Principle.

3.8.1 Visual Acuity

Visual acuity is the ability of the eye to resolve detail. The retina of eye can only focus on about a very small portion of a computer screen, or anything for that matter, at any one time (Wickens 1992). This is because, at a distance greater than 2.5 degrees from the point of fixation, visual acuity decreases by half. Therefore, a circle of radius 2.5 degrees around the point of fixation is what the user can see clearly. In the GUI world, this is the Rule of 1.7 (Sarna & George 1994). At a normal viewing distance of 19 inches, 5 degrees translates into about 1.7 inches. Assuming a standard screen format, 1.7 inches is an area about 14 characters wide and about 7 lines high (Helander 1988). This is the amount of information, which a user can take at any one time, and it limits the effective size of icons, menus, dialog boxes, etc. If the user must constantly move his eyes across the screen to focus clearly, the GUI design will cause a lot of unnecessary and tiring eye movement.

3.8.2 Information Limits

There is a limit to the amount of information, which a user can process at any one time. A GUI design rule of thumb is that the range of options or choices should never be more than five or six (Sarna & George 1994; Miller 2001). Seminal work by Miller (2001) is the basis for this rule. Miller (2001) showed that absolute identification using one-dimensional criteria was about seven items, plus or minus two. He showed that this limitation also held for memory span.

Miller (2001) introduced the concept of recoding as a method that people use to store information. Miller (2001) also pointed out that by expanding the identification criteria from one to more dimensions, people could handle more choices and remember more. Later researchers expanded on Miller's recoding to develop the concept that people chuck information together in order to remember more information (Baddeley 1994; Shiffrin & Robert 1994). This research has direct impact on GUI design, especially concerning the number of menu items and icons.

3.8.3 Gestalt Principle

The Gestalt Principle states that people (students) use a top-down approach to organizing data (Helander 1988; Wickens 1992). This principle can influence how one can organize graphical information on the screen. The Gestalt school of GUI designers have attempted to identify criteria that cause people to group certain items together in a display. Proper grouping results in a necessary redundancy of selection information that aids the user. For example, if the user knows where one item in a group is on a screen, he will expect other like items to be there also. If one groups the items in line with this expectation, it allows for accurate locating and better transfer of information to the user.

The top-down approach also allows for the development of emergent features. An emergent feature is a global property of a set that is not evident when one views each item locally. Since global processing tends to be automatic, one can argue that an emerged feature reduces the attention demand as a user operates a multi-element display. For this performance enhancement, one must use the Gestalt Principle in the initial placement, and the resulting organization must be compatible with the user's cognitive view of the task (Wickens 1992).

Having discussed the GUI consideration factors when designing an e-learning system, it is worth noting that an effective learning requires grouping composition that will allow students of different academic abilities to learn together and reach an instructional goal. This is discussed in the next section.

3.9 Heterogeneous Grouping in E-Learning

Heterogeneous grouping of students in an e-learning environment is very important. Heterogeneous Groups are groups that include students with a wide variety of instructional levels. Heterogeneous Groups stem from the education precept that a positive interdependence can arise from students with varied learning levels working together and helping each other to reach an instructional goal. In other words, it involves mixing of students of different academic abilities. Attention is given to a particular form of eLearning in which this grouping can be used. This form is called Computer Supported Collaborative Learning (CSCL). With this being said, heterogeneous grouping is very essential in CSCL. Students in these groups work together to learn and are responsible for their teammates' learning as well as their own (collaborative).

With this in mind, there have been debates as to whether heterogeneous grouping favours low-ability students in CSCL. Experiments from many researchers have suggested that heterogeneous grouping favours low-ability students in CSCL. Some of these experiments are those executed by researchers (Linchevski & Kutscher 1998; Healy 2010) with the following results as shown in table 3.2 and 3.3.

	Same-ability groups			Mixed-ability groups		
Tests	High	Intermediate	Low	High	Intermediate	Low
Differential test						
Mean	85	64	55	82	80*	78*
SD	7.8	5.6	6.2	7.5	4.3	5.1
n	33	27	14	35	26	15
Common test						
Mean	88	41	—[a]	85	65*	54
SD	8.1	5.1	—	6.9	6.1	3.9
n	33	27	14	35	26	15

Table 3.2: Mathematics achievements (means in %) at the end of 8th Grade (Linchevski and Kutscher 1998)

	Same-ability groups			Mixed-ability groups		
Tests	High	Intermediate	Low	High	Intermediate	Low
Differential test						
Mean	85	64	55	82	80*	78*
Standard Deviation	7.8	5.6	6.2	7.5	4.3	5.1
Number of Students	33	27	14	35	26	15
Common Test						
Mean	88	41	____@	85	65*	54
Standard Deviation	8.1	5.1	____	6.9	6.1	3.9
Number of Students	33	27	14	35	26	15

Table 3.3: Mathematics Achievements (means in %) at the end of 8th Grade (Healy 2010)

3.10 Conclusions

In this chapter, a brief history of eLearning, and the challenges and criticisms of e-learning were discussed. Computer aided learning, virtual learning environments and blended learning approaches were discussed. Finally, e-learning systems for teaching mathematics collaboratively in primary school education, the GUI consideration factors when designing those systems and the heterogeneous grouping of students in this e-learning environment were discussed.

The application used for this research was designed using RAD methodology and was modularised. Some careful considerations were made on the GUI factors during the development of the application. This is discussed in the next chapter.

4. Designing the Experiment Part 1: Research Application

4.1 Introduction

This chapter discusses the packages used in the application for this research and the concept used in its development, and goes further to discuss the GUI factors considered in the development of the application. In addition, it discusses the software development methodology used for the application development, the requirements analysis of the application and finally discusses the design phase of the application. This application was designed using the CASE tool, IBM Rational Software Architect, Standard Edition, V7.5.0.

The name of the application employed in the experiment for this research is Math Learning Collaborator (MLC). In addition, the MLC System is solely the work of the author of this research. The MLC System incorporates seven basic packages (modules) that it employs to deliver the needs of the stakeholders' or the participants (Presentation Primary School Students and teacher) in order to create an environment for a successful experiment. These packages includes other sub packages. Each package at the lowest module hierarchy includes classes that run an aspect of a desired functionality. In other words, the concept of modular programming was employed in the MLC System design process. Figure 4.1 depicts a very simple MLC System Module Structure. (See Appendix B for more detailed diagram)

The classes in these packages or modules are omitted from this diagram. The class diagrams are included in appendix D. The authors took a decision to separate the software development lifecycle and the database development lifecycle into different chapters to prevent any ambiguity, misunderstanding of terms or use of terms interchangeable by the readers of this document. Nevertheless, their designs and developments went as parallel activities.

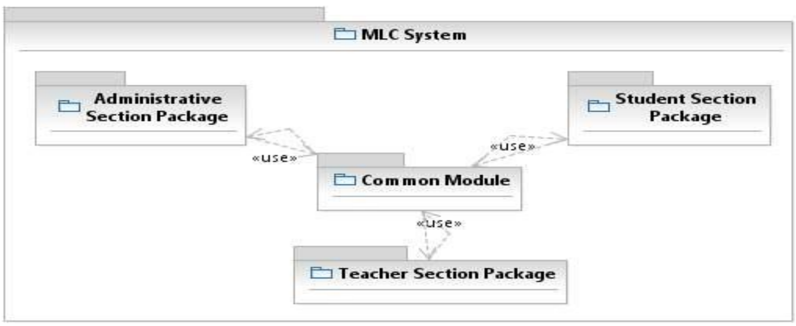

Figure 4.1: MLC System Module Structure. Diagram created using Rational Software Architect Standard Edition, V7.5.0. (Author)

4.2 Purpose of the Packages used in MLC System

4.2.1 Common Module

This module or package has a common coupling (2-direction dependency) with all the packages in the MLC system. It purpose is to provide shared features and services to all modules in the MLC System, and it includes nine sub modules that provides these shared services to other modules. (See appendix B for these sub modules)

1. Assessment Module: This module provides assessment service to other modules in the same level of hierarchy that need them.
2. Authentication Module: This module provides authentication service to other modules in the same hierarchy that need them.
3. Miscellaneous Module: This module provides miscellaneous (unrelated) services to other modules in the same hierarchy that need them.
4. Registration Module: This module provides registration service to other modules in the same hierarchy that need them.
5. Session Module: This module provides session service to other modules in the same hierarchy that need them.
6. Welcome Module: This module provides acceptance and greeting service (welcome service) to other modules in the same hierarchy that need them.
7. Database Module: This module provides database service to other modules in the same hierarchy that need them.
8. Network Module: This module provides network service to other modules in the same level of hierarchy that need them.
9. Error Module: This module Provides error control and prevention services to other modules in the same hierarchy that need them.

4.2.2 Teacher Section Package (TSP)

The Teacher Section Package is responsible for providing all the necessary features and services required by a teacher to complete necessary tasks during the experiment. TSP includes six sub modules that provides these services to the teacher. These include:

1. Assessment Module: This module provides assessment services required by the teacher to complete necessary assessment tasks. Assessment Module contain four sub modules or packages via which it provides these services. These include:
   - Artefact Assessment Module that provides artefact assessment service e.g. a teacher

rating his or her copy of the artefact (MLC System).

- Device Assessment Module that provides device assessment service e.g. a teacher rating his or her device.
- Student Assessment Module that provides student assessment service e.g. a teacher rating the students
- Teacher Assessment Module that provides teacher assessment service e.g. a teacher rating him or herself.

2. Teaching Module: This module provides teaching service required by a teacher to complete teaching tasks e.g. a teacher selecting and sending learning materials to student devices (teaching the students).
3. Student Removal Module: This module provides student removal service required by a teacher to complete student-deleting tasks e.g. a teacher removing students from his or her class during the experiment.
4. Test Module: This module provides test service required by a teacher to complete test tasks e.g. a teacher selecting and sending test materials to the student devices (testing the students).
5. Common Module: This module provides common or shared services internally to other sub modules in TSP, which allows these sub modules to complete their goals in serving the teacher.
6. Registration Module: This module provides registration services required by a teacher to complete registration tasks. The sub package (Registration Module) contains two sub packages that provides these registration services. These include:
   - Student Registration Module that allows the teacher to register students.
   - Teacher Registration Module that allows the teacher to register him or herself.

4.2.3 Student Section Package (SSP)

The Student Section Package is responsible for providing all the necessary features and services required by a student to complete necessary tasks during the experiment. SSP includes three sub modules that provides these services. These include:

1. Assessment Module: This module provides assessment services required by a student to complete assessment tasks. Assessment Module contains five sub packages that have individual purposes of providing these assessment services. These include:
   - Artefact Assessment Module that provides artefact assessment service e.g. a student rating his or her copy of the artefact (MLC System).

- Devise Assessment Module that provides device assessment service e.g. a student rating his or her device.
- Formative Assessment Module that provides formative assessment service e.g. a student rating him or herself or rating his or her group members.
- Summative Assessment Module that provides summative assessment services e.g. a student test material being marked automatically when he or she submits the test material.
- Teacher Assessment Module that provides teacher assessment service e.g. a student rating his or her teacher.

2. Session Module: This module provides session services required by the student to complete necessary tasks during sessions in the experiment. Session Module contains three sub modules or packages that have individual purposes of providing these session services. These include:
   - Common Module that provides common or shared services internally to other sub modules in Section Module, which allows these sub modules to complete their goals in serving the student.
   - Lesson Module that provides lesson services required by the student to complete lesson session. Lesson Module contains four sub modules that have individual purposes of providing these lesson services. These include:
     - Common Module that provides common or shared internal services to other sub modules in Lesson Module.
     - Lesson Material Module that provides lesson material service e.g. creating lesson material for a student to learn.
     - Solved Exercises Answers Module that provides answers-to-exercises service e.g. creating answers to exercise solved by a student.
     - Solved Exercises Material Module that provides lesson exercises service e.g. creating an exercise for a student to solve during lesson.
3. Test Module: This module provides test services. Test Module consists of two sub packages or modules that have individual purposes of providing these test services. These include:
   - Common Module that provides common or shared internal services to classes in Test Material Module sub package.
   - Test Material Module that provides test material service e.g. creating test materials for a student.

4.2.4 Administrative Section Package (ASP)

The Administrative Section Package is responsible for providing all the necessary features and services required by an administrator to complete necessary tasks during the experiment. ASP includes two sub modules that provides these services to the administrator. These include:

1. Common Module: This module provides common or shared internal services to sub packages in Assessment Result Display Module. This Common Module sits out side Assessment Result Display Module because it does not contain classes related to assessments.
2. Assessment Result Display Module (ARDM): This module provides assessment result display services. ARDM consists of four sub modules that have individual purposes of providing these assessment result display services. These include:
   - Artefact Assessment Result Display Module that provides artefact assessment result display service e.g. displaying the results of artefact assessment to the administrator.
   - Common Module that provides common or shared internal services to sub Packages in Assessment Result Display Module.
   - Device Assessment Display Module that provides device assessment result display service e.g. displaying the results of device assessments to the administrator.
   - Formative Assessment Result Display Module that provides formative assessment result display service e.g. displaying the results of student assessment to the administrator.
   - Teacher Assessment Result Display Module that provides teacher assessment result display service e.g. displaying the results of teacher assessment.

The MLC System was designed considering some factors that were discussed in the literature review. This is discussed in the next section.

4.3 MLC System Design factors

Several factors, which were discussed in the literature review of this research was considered when designing the MLC System. Initially, consideration was given to the primary type of learning theory that would govern the design of the system, would it be behaviouristic, cognitivistic or constructivistic? After some discussion with the end-users, and supervisor, it was decided that the system would embrace all three paradigms. Secondly, in terms of the design of the individual lesson, which models of Instructional Design would be used to guide this process? All the models mentioned in the literature review were incorporated into the final design, with special focus on: the ICARE model, Merrill's Component Display Theory, and Gagne's Nine Events of Instruction. An example follows to illustrate how Gagne's Nine Events of Instruction were incorporated and factors considered when designing the MLC System GUI.

4.3.1 Incorporation of Gagne's Nine Events of Instruction

MLC System incorporates Gagne's Nine Events of Instruction:

1. Using the welcome and acceptance feature to gain student attention.
2. Using the guidance feature (collaborative scripts) to inform students of their objectives.
3. Using the learning material content to stimulate recall of prior learning for students.
4. Using multiple versions of the same image to present examples to the students to broaden their understanding and concepts. It also includes good vocabularies that allowed the students to grasp new terminologies.
5. Using the collaborative scripts and collaborative-learning-in-practice video to allow the teacher use scaffolding to advise the students on their role-playing, the things that are required of them in learning and analogies for knowledge construction.
6. Using the learning exercise feature to allow the student to do exercise after learning in order to help them internalize new skills and knowledge and confirm correct understanding of these concepts. The learning exercise feature in addition employs real world examples (context-rich).
7. Using the answers-to-exercises feature incorporated into MLC System in which the students checked their selected options for exercises to the answers to those exercises, and then took necessary steps to adjust their learning.
8. Using the assessment feature that allowed the teacher to conduct post-tests on the students and check their performance in summative assessment, and restructure the formative assessment based on the outcome of the summative assessment.
9. Using the learning material feature in which the content was paraphrased to the level of understanding of the students, and examples (diagrams, texts etc.) were used for illustrations to help the students internalize new knowledge.

4.3.2 MLC System GUI Design Considerations

Based on careful consideration of the user interface design factors discussed in the literature review, the authors of this research paper now came to the decisive conclusion that they can derive basis GUI standards from basic human factors. These standards are the presentation of information, the grouping of information, and information sequencing.

4.3.2.1 Presentation of Information

The amount of information to present was MLC System most basic GUI design considerations. Bakewell (1993), Helander (1988) and Reiterer (1993) showed that making screens less crowded improves screen clarity and readability. As such, the guidance that the interface should display only what the user needs to perform the current operation was followed by disabling the unnecessary ones. Empirical researchers showed that limiting the information to that necessary for the user reduces errors and time to perform tasks. Errors and performance time increase as the GUI presents more information. The MLC System screen was well designed, and according to Helander (1988) and Lin and Dan (1994), a well-designed screen can reduce time needed to perform a task by as much as 40%.

<u>Ways information was presented in the MLC System</u>

- **Balance between full words and abbreviations**: The MLC System used concise words. This concise words used in MLC System was a trade-off or balance between full words and abbreviations e.g. instead of using ‘rate the students in your class’ for an option in a teacher section; it was made concise using ‘rate the students’.
- **Avoid unnecessary detail**: Unnecessary details and icons were avoided in the user interface of the MLC System since elaborate icons add nothing to performance. Studies show that when icon designs are too complex, time to complete a task actually increases (Benbasat & Peter 1993). The MLC System enabled only the options necessary for the students and teacher to complete particular tasks at any given moment, and thus reducing unnecessary detail that may overwhelm the users.
- **Use familiar data formats**: With familiar formats, the user will need less information to complete the task. Familiar formats were used in the MLC System GUI so that the students and teacher can easily understand them without any complications e.g. the option ‘enter test session’ allows a student to know instantly that it will take him or her to where he or she will take a test.

- **Use tabular formats with column headings**: Tabular formats allow for efficient labelling of related data. It is especially preferable for data location tasks. Simply splitting items on one long line into two lines result in productivity improvements of 20% (Sarna & George 1994). In addition, LaLomia and Coovert's research in (Helander 1988) showed that locating a data value was quicker in tabular form then in a random or graph format. MLC System use tabular format to present analytic information e.g. student results, registration records etc. with descriptions on top of the information.

4.3.2.2 Grouping of Information

The information presented by the MLC System was properly grouped. Proper grouping improves the information's readability and can highlight relationships between the information (Helander 1988). There are several techniques employed to aid in the grouping of information in MLC System, which include:

- **Colour**: Presenting different groups with different colour clearly creates some degree of grouping among the elements of the same colour. GUI that effectively utilizes colour will increase productivity (Bakewell 1993). However, overuse of colour degrades performance. As a result, colours were effectively and carefully utilized in grouping information in the MLC System. Necessary measures were taken to keep them below excessive but within effective use.
- **Graphical Boundaries**: Drawing boundaries around elements is the most common method of grouping elements in GUI according to most empirical research. Although there is no empirical evidence to show that these groupings improve performance, users prefer this type of groupings compared to other methods. Boundaries were used to group information in the MLC System.
- **Highlighting**: Besides colour, there are several other methods of highlighting including reverse video, brightness, underlining, and flashing. Brightness was chosen as means of highlighting in the MLC System, as it conforms to the users' needs of the application. Flashing was only used to convey urgent information to the users as it conforms to most research.

4.3.2.3 Information Sequencing

The MLC System screen was laid out in a manner that easily allows the user to find any information on it. The optimum sequence for the MLC System screen presentations is a collection of various factors, including:

- **Sequence of use**: The MLC System presented the information to the users (students and teacher) in the order that they effectively utilized it.
- **Conventional Usage**: Conventional usage was employed for the GUI design of the MLC System. For example, in the standard window layout, the help option is usually to the far left of the window.
- **Importance**: Information that is more important was placed on a prominent location in the MLC System GUI windows. For example, the MLC System GUI led off with the required options and end with the optional ones.
- **Frequency of use**: The most frequently utilized options were placed at the beginning of sets of options in the MLC System. For example, 'send lesson material' option is at the top since it is frequently used.
- **Generality versus Specificity**: In the MLC System GUI screen, the more general items preceded the more specific items if there was a hierarchical relationship among the terms e.g. the option 'student' preceded the option 'group'.

The goal of the MLC System GUI is to allow the users to work through the computer and application concentrating on the primary cognitive task. This goal was achieved by applying all the discussed steps above. Thus, caution was taken so that primary focus of the students and teacher should not be shifted towards the user interface. According to Benbasat (1993) and Norman (1988), any attention devoted to the interface interferes with the main task.

4.3.3 Ramifications of MLC System Design Decisions

According to (Bakewell 1993; Boeri & Hensel 1996), training costs are usually one to three times the cost of the actual software. However, one consistent result is that an increased operational knowledge transfer between applications reduces training costs (Harding 1989). Therefore, using effort in place of cost it could be noted that one consistent result of the MLC System design decisions is that the increased operational knowledge transfer between the modules used in the MLC System reduced the training effort of the developers. The good GUI design of the MLC System drastically reduced the required training time for the users to learn the application, and according to (Comaford 1999), a good GUI design reduces required training time to 20-30 hours for a user to learn an application. Additionally, due to good GUI employed in the MLC System the users' perception of it improved since the user's first 15 minutes of usage formulates the lasting impression of an application (Winograd 1995).

[Note: Loose or low coupling was used in the MLC System development; meaning one component (class, package) can use another component or components, having little or no knowledge about the implementation of the features in the used components]

4.4 *Why was the concept of Modular Programming used?*

The concept of modular programming was used for the development of the MLC System for the following reasons.

- *Size, Separation of Concerns and Maintainability*: The MLC System is a large system that has more than hundred classes with a size of more than 64 MB, and according to Haas (2013) and Microsoft (2013), the problem of large scale software programs that are difficult to maintain and debug can be solved by modular programming. In other words, it results to a structured concept as a complex problem can be broken into simpler tasks. Microsoft (2013) also noted that modular programming is suited for user interface applications, and can make an application more flexible and easier to extend in the future, and thus, allows a developer to break the application into manageable pieces. Each piece encapsulates specific functionality, and integrated through clear but loosely coupled communication channels. This strategy of developing a program is therefore, very beneficial. Modular programming separates or isolates concerns, such that modules perform logically discrete functions.
- *Namespaces Resolution*: Modularization resolves names space clashes in an application by allowing classes with the same names but in different packages not to have a name clash.
- *Reuse*: It is much easier to reuse software modules or packages that are dedicated to specific purposes.
- *Decoupling and Coupling during Testing*: Modularization allows a developer to decouple some specific areas of the application for unit testing and coupling it back after this testing.

These beneficial characteristics of modular programming were taken into account to develop, test and debug MLC System, transforming it to a desired or acceptable working software solution for the experiment.

4.5 MLC System Software Development Methodology

Rapid Application Development (RAD) was employed as the Software Development Methodology for the development of the MLC System.

4.5.1 What is RAD?

Martin (1991), who first coined this term, defined RAD as a development lifecycle used to get much faster development and higher-quality results than those achieved with the traditional lifecycle. Kettemborough (1999) defined RAD as a way of dealing with development of computer systems, which joins Computer-Assisted Software Engineering (CASE) tools and techniques, user-driven prototyping, and stringent project delivery time limits into a potent, tested, reliable formula for top-notch quality and productivity. Kettemborough (1999) went forward to note that RAD drastically increases the quality of finished systems while reducing the time it takes to develop them. Online Knowledge defines Rapid Application Development (RAD) as a methodology that allows organizations to skilfully build systems faster while reducing development costs and maintaining quality (CASEMaker Inc 2000). Online knowledge also added that using a series of proven application development techniques, within a well-defined methodology achieves this goal (CASEMaker Inc 2000).

RAD can be viewed as a methodology used in projects that emphasizes development speed and, if well executed, can be structured and disciplined. It focuses on the delivery of the product, the client's needs and involves the client from the start. RAD methodology uses minimal planning in favour of rapid prototyping, allowing software to be developed faster and makes it easy to change the requirement. RAD approach is suitable for projects where objectives are well defined and narrow, data set for project already exists, decision can be taken quickly, development team is small and architecture of project is well defined. It uses both iterative and incremental approach, and in addition keeps project plan updated, applies development fundamentals and manages risks to avoid catastrophic setbacks. RAD is very important as Hambling (2000) noted that one of the key quality characteristics of application or systems development is the ability of the information system to emerge to meet new requirements. Hambling (2000) went forward to note that systems must be capable of rapid evolution if they are to deliver real value to the clients, but systems that cannot evolve rapidly offer little or no support to their users, who in turn become less responsive to their environment and consequently incur increased risk of failure in the marketplace.

4.5.2 Why was RAD chosen for MLC System?

From the above discussion, some reasons are listed as to why RAD was chosen as software development methodology for the MLC System. These reasons are:

- It reduces development time (quick launch of software to users).
- It allows applications to be developed using modular programming concept (incremental).
- It permits rapid prototyping and quick decision
- It increases reusability of components.
- It favours small development team.
- It permits management of risks to avoid catastrophic setbacks.
- It is suitable for software project with well define objectives
- It leads to higher quality systems that work and adapt to requirements change.
- It permits quick initial reviews.
- It encourages customer feedback (allowing flexibility in requirements and project plan updates)
- It permits users' integration from the very beginning.
- It suitable for GUI applications (allowing developers the ability to rapidly demonstrate screen layout and logic flow).
- It permits developers to know and understand how to manipulate various CASE tools during development thereby broadening their experience.

Shown below in figure 4.2a is the RAD Model, which was referenced for the development of the MLC System. As shown in figure 4.2a, the design and construction phase of the MLC System went in parallel. Figure 4.2b shows the elaboration of the design and construction phase of the diagram in figure 4.2a to show the actual steps taken during the design and construction phase of the MLC System (within the circular loop). Figure 4.3 shows the four aspects of RAD, which includes methodology, people, management, and tools. Measures were taken to ensure that none of these aspects was missing during the MLC System development. These aspects were resolved in table 4.1, which shows the four specific aspects of RAD for the MLC System.

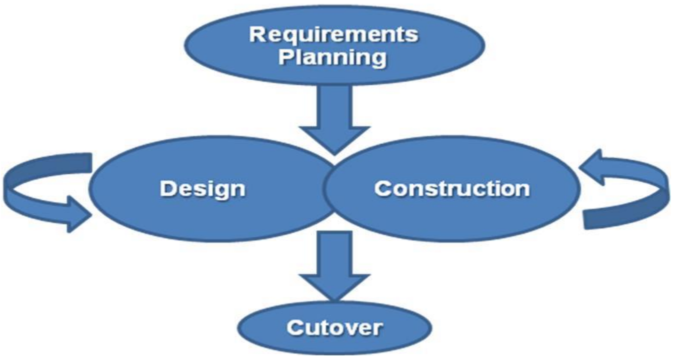

Figure 4.2a: RAD Model (RAD Development 2012)

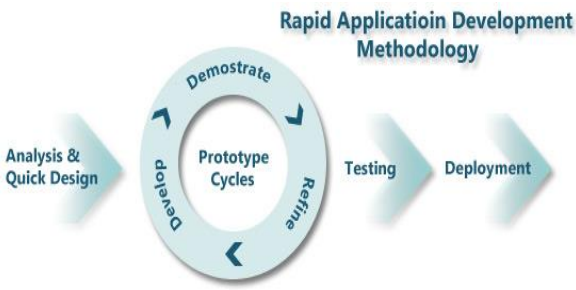

Figure 4.2b: RAD Model depicting the elements of construction and design shown in figure 4.2a within a circular loop (IT Evolution 2010)

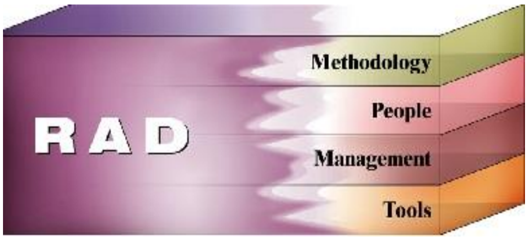

Figure 4.3: Four Aspects of RAD (RAD Development 2012)

Methodology	People	Management	Tools
RAD	Presentation Primary School students and teacher	MLC System Development team (author)	IBM Software Architect Standard Edition.
			NetBeans IDE
			Erwin Data Modeller

Table.4.1: MLC System Four Aspects of RAD. (Author)

4.6 Requirement Analysis

This section covers the MLC System users' needs and their analysis. Before going ahead to discuss the analysis of the user requirements for the MLC System, some terms need to be understood.

4.6.1 Use case Definition

A use case is the description of a system behaviour during its response to a request that evolves from outside of that system. It shows or describes interactions between one or more actors and a system. By detailing scenario driven threads via the functional requirement of a system, use-case techniques can be used to capture the behavioural requirement of that system.

Use case diagrams do not give the detail of the use cases but relevant concise information between use cases, actors, and systems. Visual Studio (2013) notes: "*A use case diagram does not show the detail of the use cases: it only summarizes some of the relationships between use cases, actors, and systems. In particular, the diagram does not show the order in which steps are performed to achieve the goals of each use case.*"

A scenario is a brief story that describes the hypothetical use of a system. It describes the functionalities of the system in satisfied and unsatisfied conditions.

- It tells who is using the system and what they are trying to achieve or accomplish.
- Provides a realistic, fictional account of a user's constraints: when and where they are working, why they are using the system, and what they need the system to do for them.
- Describes any relevant aspects of the context in which the user is working with the system, including what information the user has at hand when beginning to use the system.
- Gives the user a fictional name, but also identifies the user's role, such as student, teacher, administrator etc.
- Indicates what the user regards as a successful outcome of using the system.

An actor is an entity outside the system with a characteristic role of a person, system or some other external entity. In other words, an actor is a class that forms a system boundary, and it is not within the responsibility of the systems designer/analyst. It is usually linked to one or more use cases that are organised or grouped in a non-overlapping logical manner. Thus, anything that is part of the system is not an actor e.g. Error Module is not an actor since is part of the system, but database server (computer), teacher, student and administrator are actors since they exists outside the system boundary. There are two types of actors:

- Active actors, whether primary or secondary, initiate a use case e.g. teacher, student and administrator for the MLC System.
- Passive actors receive input from a system, and are activated by this to carry out an activity e.g. application/database server for the MLC system.

4.6.2 Sequence Diagram Definition

Sequence diagram in UML is a kind of interaction diagram that shows how classes (processes) operate with one another and in what order. It is a construct of a message sequence chart.

- A sequence diagram shows as parallel vertical lines ("lifelines") different processes or objects that live simultaneously, and as horizontal arrows, the messages exchanged between them in the order in which they occur. This allows the specification of simple runtime scenarios in a graphical manner.

4.6.3 Steps used in MLC System requirement analysis

- All the necessary information (data, activities etc.) about the processes involved in mathematics collaborative learning and teaching were gathered from several research papers and Irish Math Curriculum for Fourth-Class Primary School Students.
- The stakeholders (Presentation Primary School students and teacher) were interviewed at considerable frequency or when necessary as needs arose to get their views or perspectives about what they expect the system to do, or should be present in the system and how the system should interact with them to achieve their desired goal.
- These activities were then grouped accordingly in categories.
- Each group of related activities evolved into a feature called use case.
- Each use case was associated to either a person or system called an actor of which there were four categories e.g. teacher, student, administrator and database/application server (computer).

[Note: the database/application server has two roles. The first is to provide database services to the computers used in the experiment, and the second is to provide application services e.g.

sending objects to the computers that request for them. As a result, these two roles were integrated into one called database/application server]

- Scenarios resulting from particular activities were designed.
- Each of these features was elaborated during analysis to make provision for more activities.
- Then, the sequence diagrams were designed to link these activities in time reference and checked if there was any activity missing, and in the case of any missing activity, the use case scenarios were referenced for modification and then the sequence diagram updated.

4.6.4 Use case Diagrams

In this section, the use case diagrams, which describes the users of the MLC System and what these users do with the system, are discussed, which also forms a means of documenting the user requirements for the system. The discussion here will be precise and concise. Before going further, the multiplicity used will be made clear so that further discussion of it will not be mentioned to avoid unnecessary exaggerations of details except for the first use case where it is explained. Thus, the following are the multiplicity notation and their indications.

- 1 - To state that exactly one instance of this role participates in each link.
- 1..* - To state that one or more instance of this role participate in each link.
- 0..1 - To state that participation is optional.
- 0..*- To state that zero or more instances of this role participate in the link.

With this in mind, the active actors (teacher, student and administrative) initiate or trigger the activity that starts the interactions between them and the system.

4.6.4.1 MLC System Initial Stage Use case Diagram

Shown below in figure 4.4 is the initial requirement analysis diagram of the actor-use case pair for the use case (use MLC System). It shows the student, teacher and administrator using the MLC System. As shown in the diagram, a teacher can be an administrator. As shown in figure 4.4, an instance of the actor "student" can use zero or one copy of the MLC system at a time, and a copy of MLC System can only be used by a student. The same goes for the teacher and administrator. This simply means the student is not allowed to use the application on two or more computers at the same time but one. In addition the multiplicity (0..1) simply means that a student might not use the application due to some conditions e.g. he or she can be absent in one or more class sessions and thus cannot use the application in those sessions.

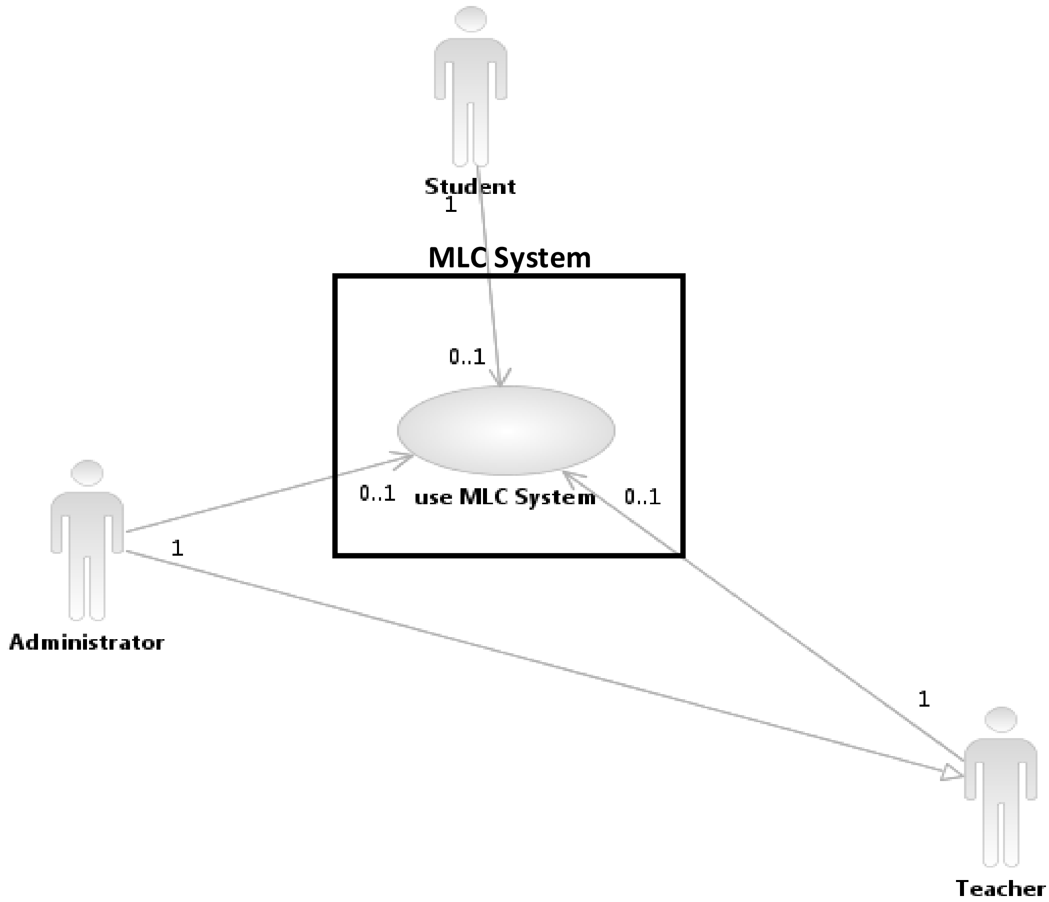

Figure 4.4 Actor-use case pair for the use case "use MLC System" involving three actors. Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

The final use case diagram for the teacher evolved, after intensive elaboration of the base use case "use MLC System" shown in figure 4.4. These are shown below. The teacher use case diagram was broken down into three parts for the purpose of simplicity.

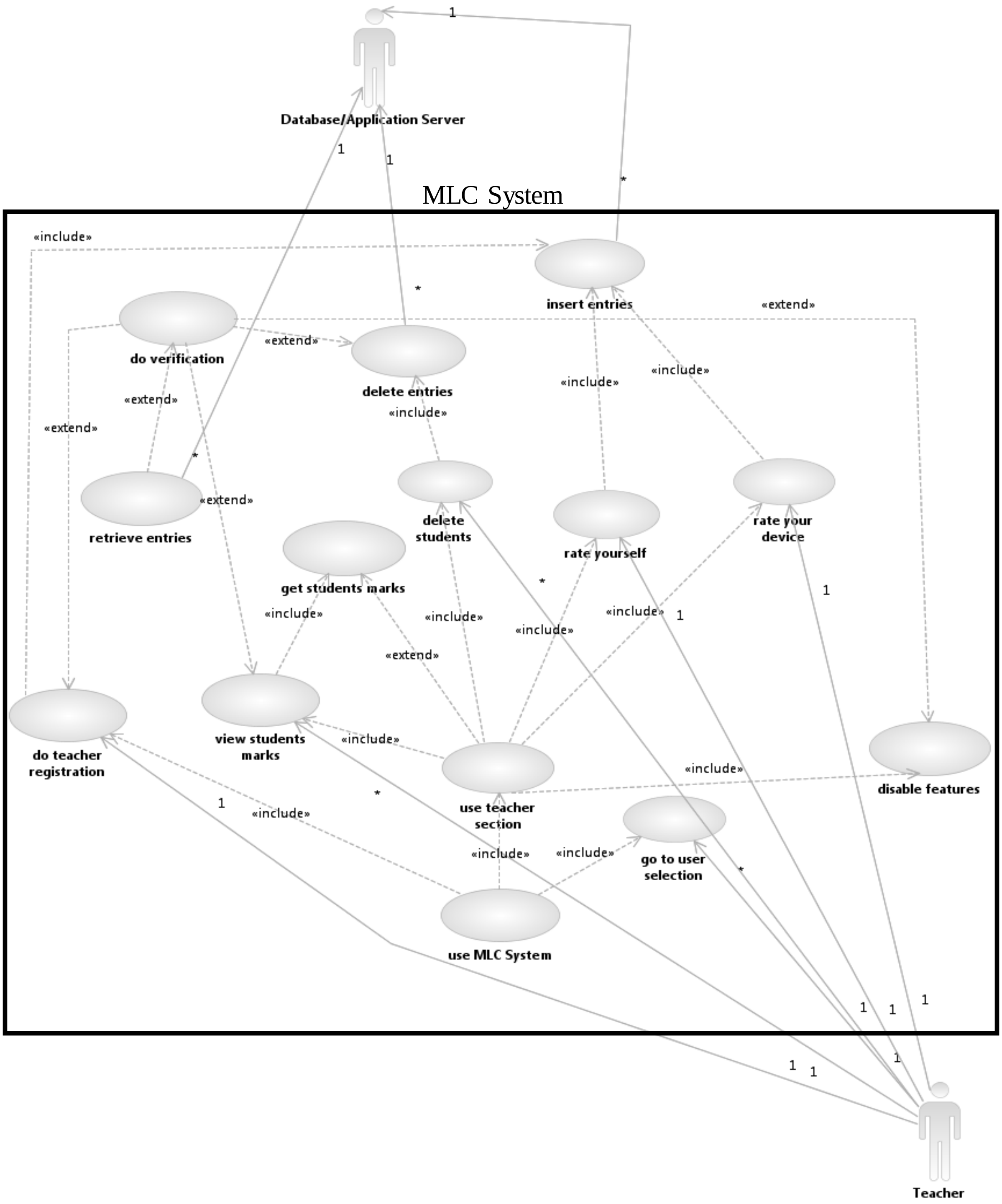

Figure 4.5: Actor-use case pairs depicting the use cases involving the actor "teacher". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

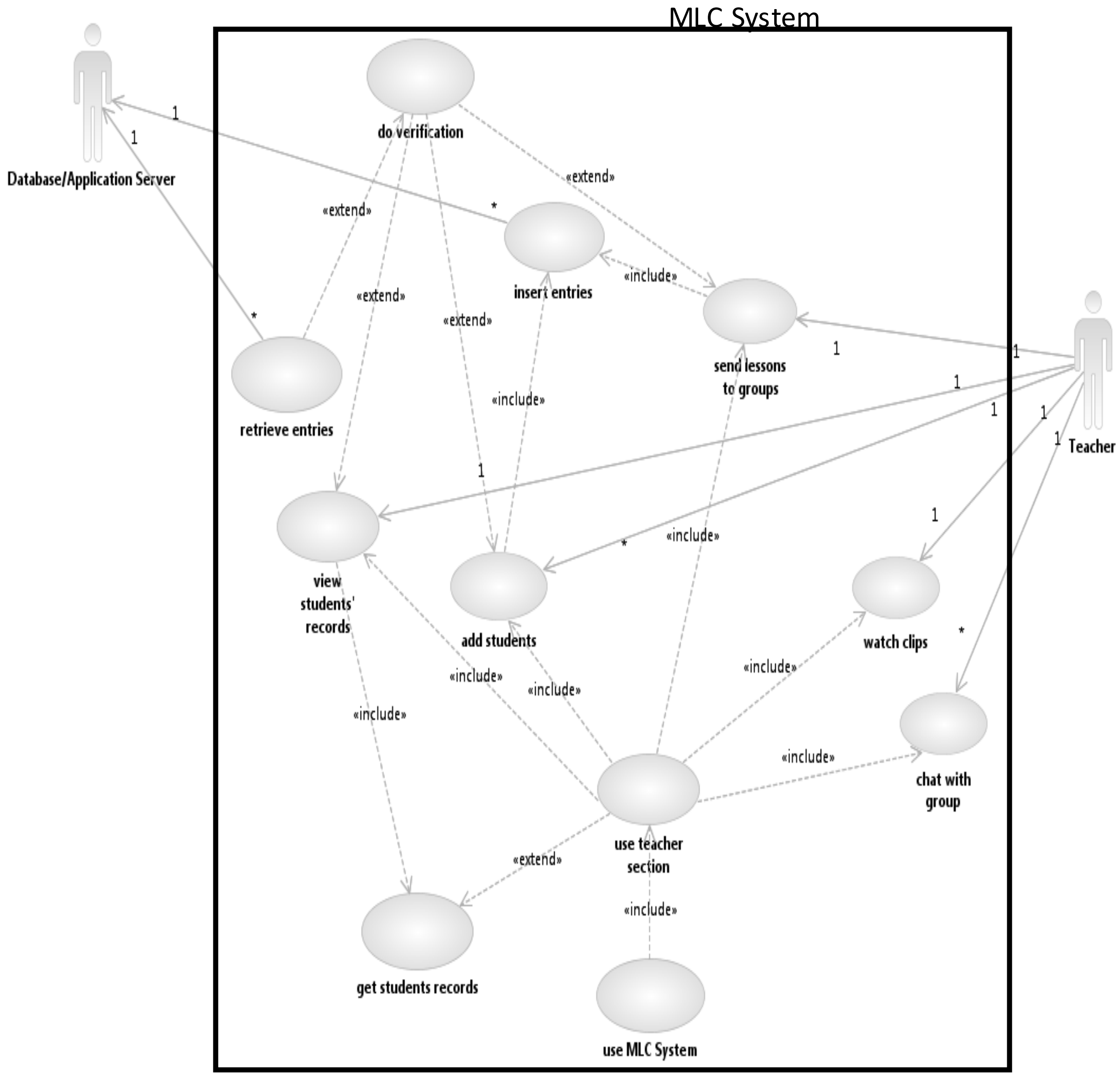

Figure 4.6: Actor-use case pairs depicting the use cases involving the actor "teacher". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

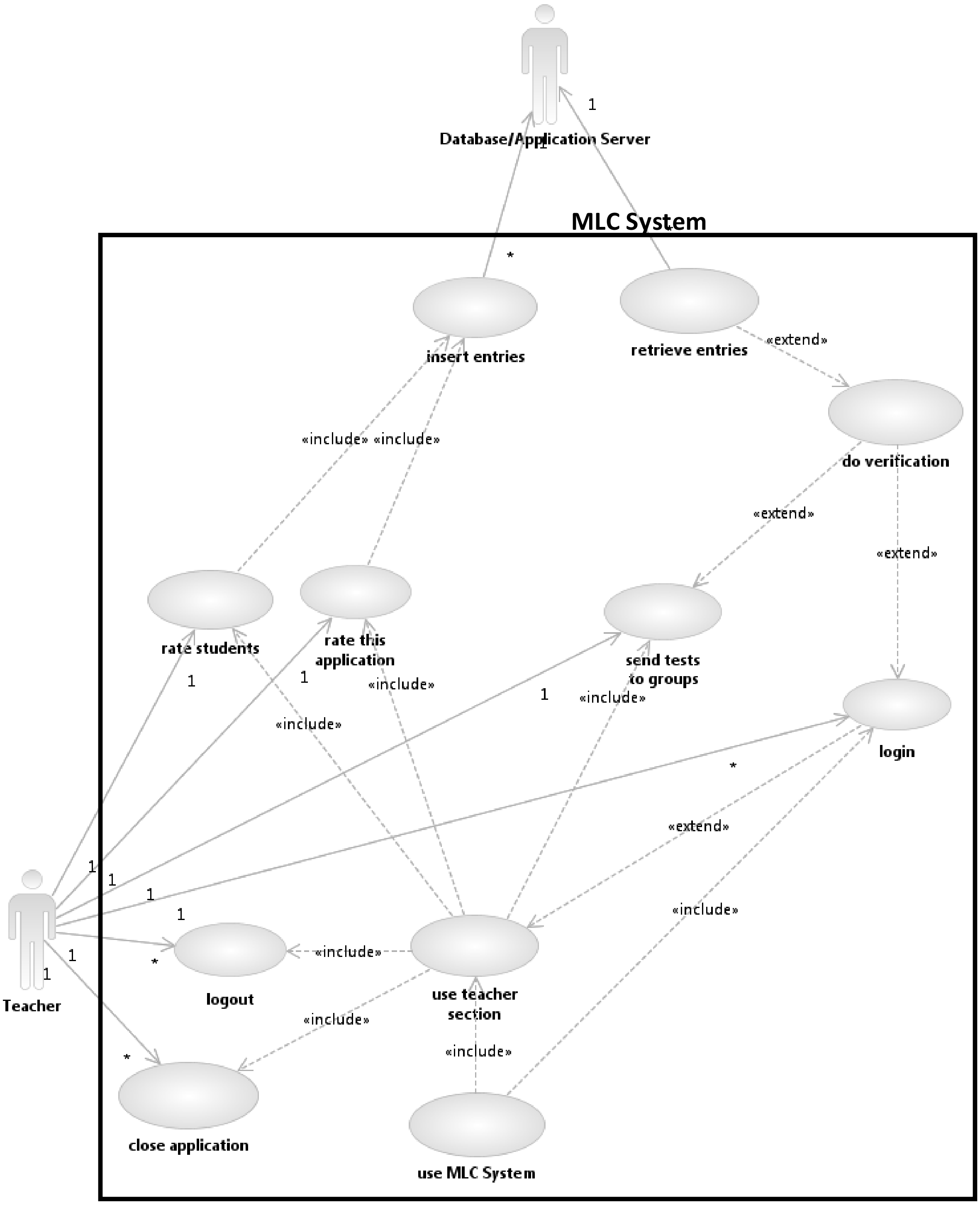

Figure 4.7: Actor-use case pairs depicting the use cases involving the actor "teacher". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

The final use case diagram for the student evolved, after intensive elaboration of the base use case "use MLC System" shown in figure 4.4. These are shown below. The student use case diagram was broken down into four parts for the purpose of simplicity.

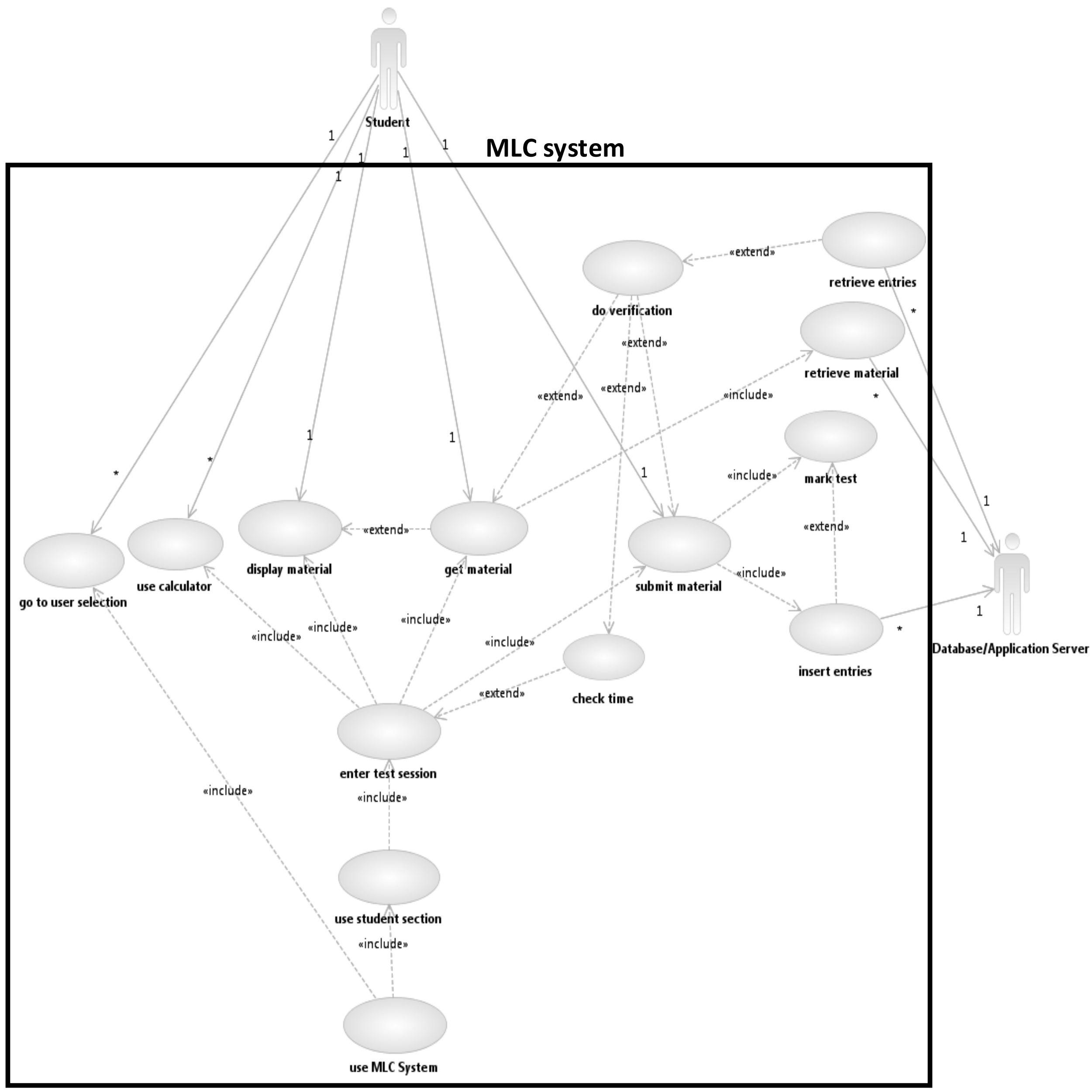

Figure 4.8: Actor-use case pairs depicting the use cases involving the actor "student". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

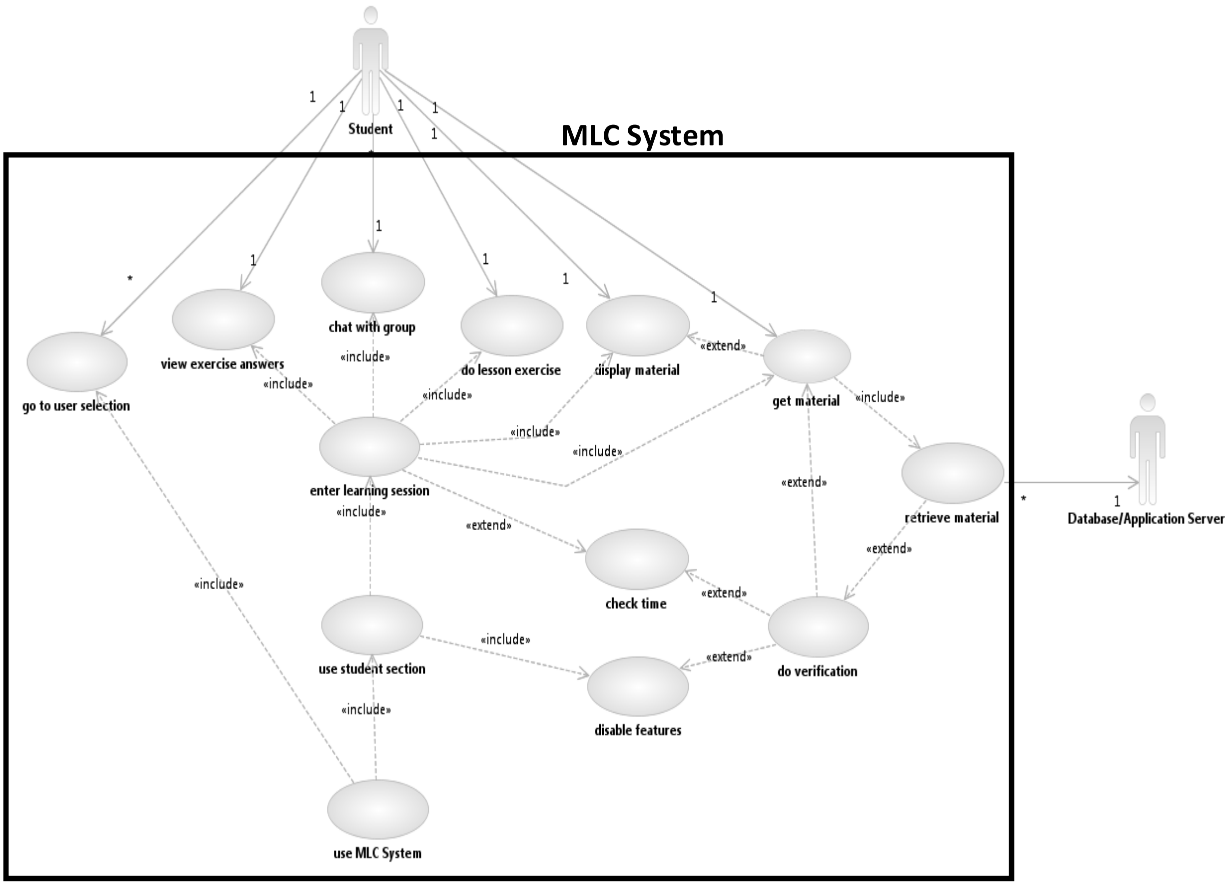

Figure 4.9: Actor-use case pairs depicting the use cases involving the actor "student". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

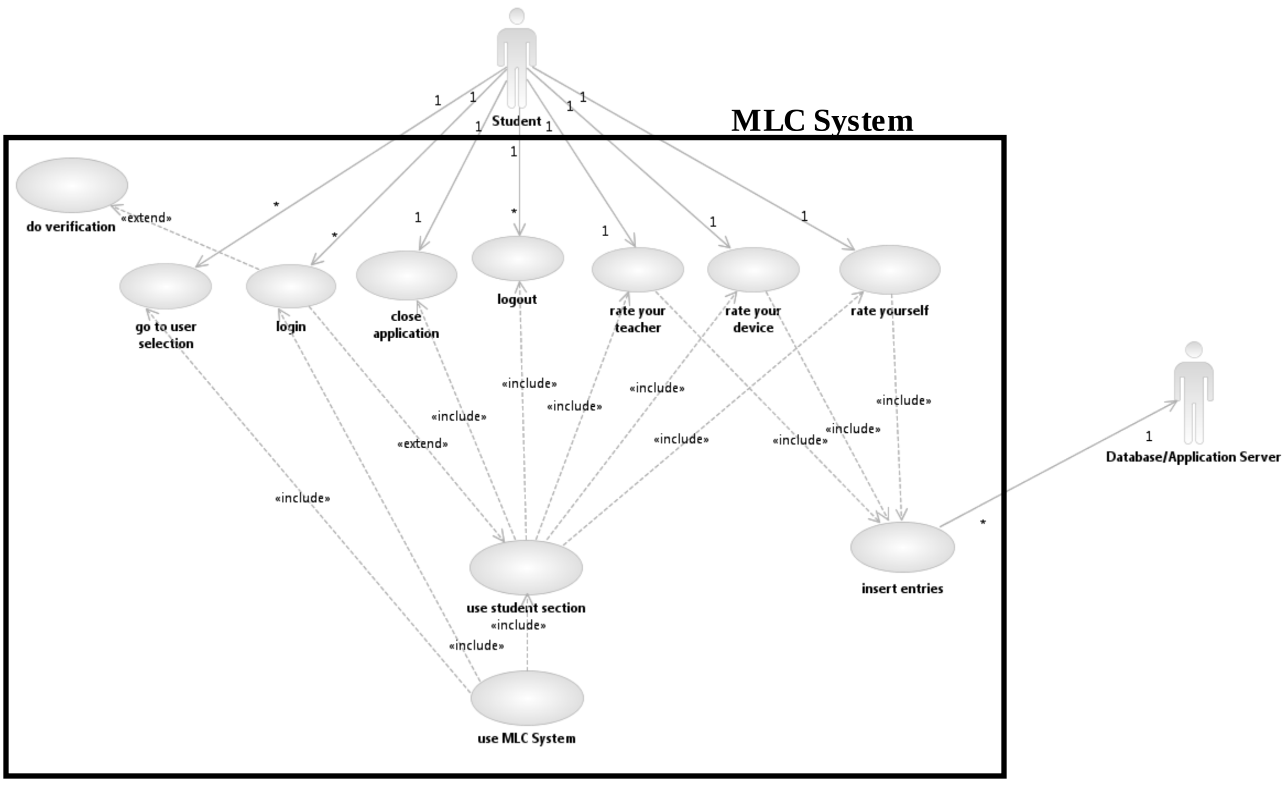

Figure 4.10: Actor-use case pairs depicting the use cases involving the actor "student". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

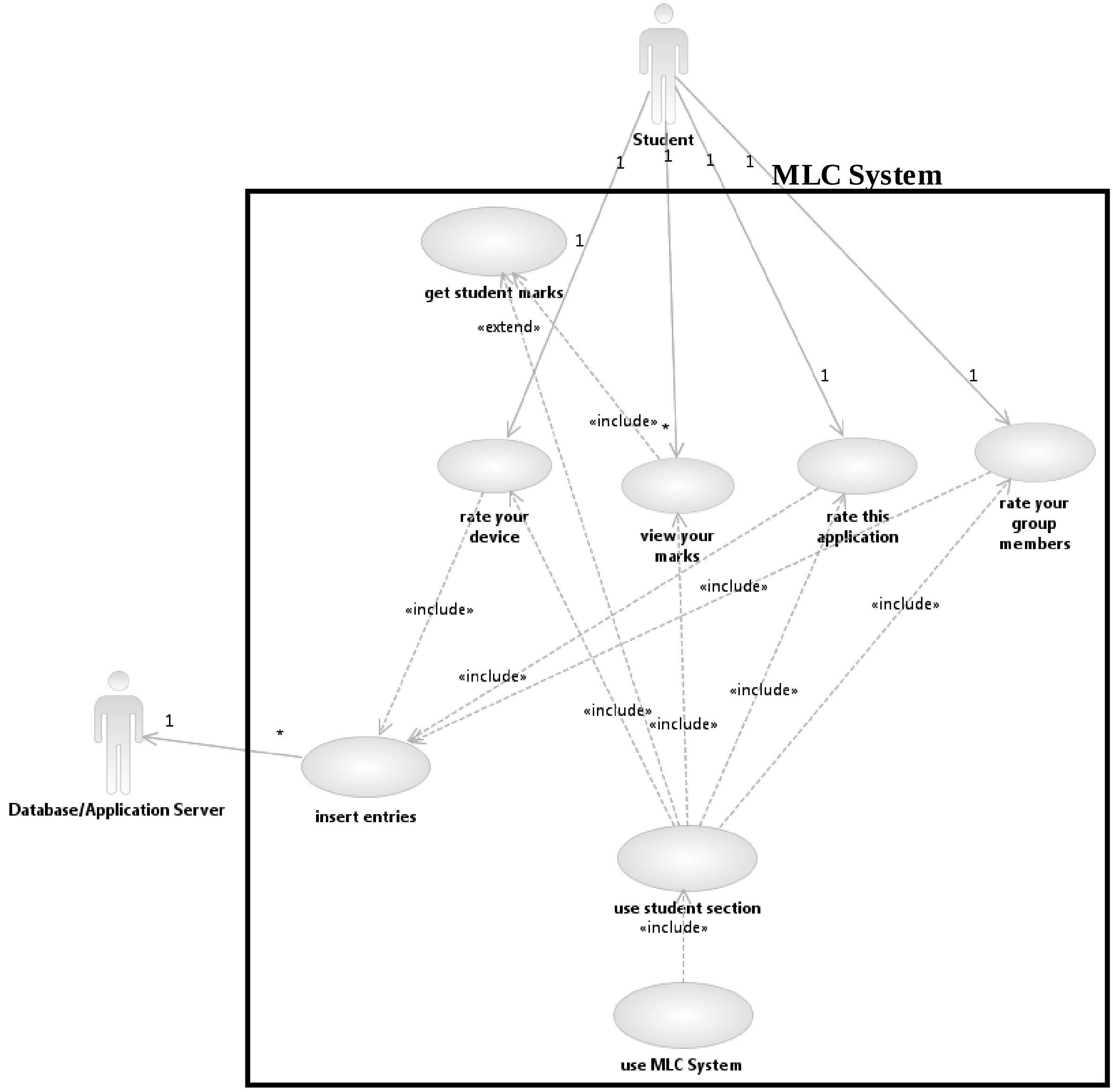

Figure 4.11: Actor-use case pairs depicting the use cases involving the actor "student". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

The final use case diagram for the administrator evolved, after intensive elaboration of the base use case "use MLC System" shown in figure 4.4. These are shown below. The administrator use case diagram was broken down into three parts for the purpose of simplicity.

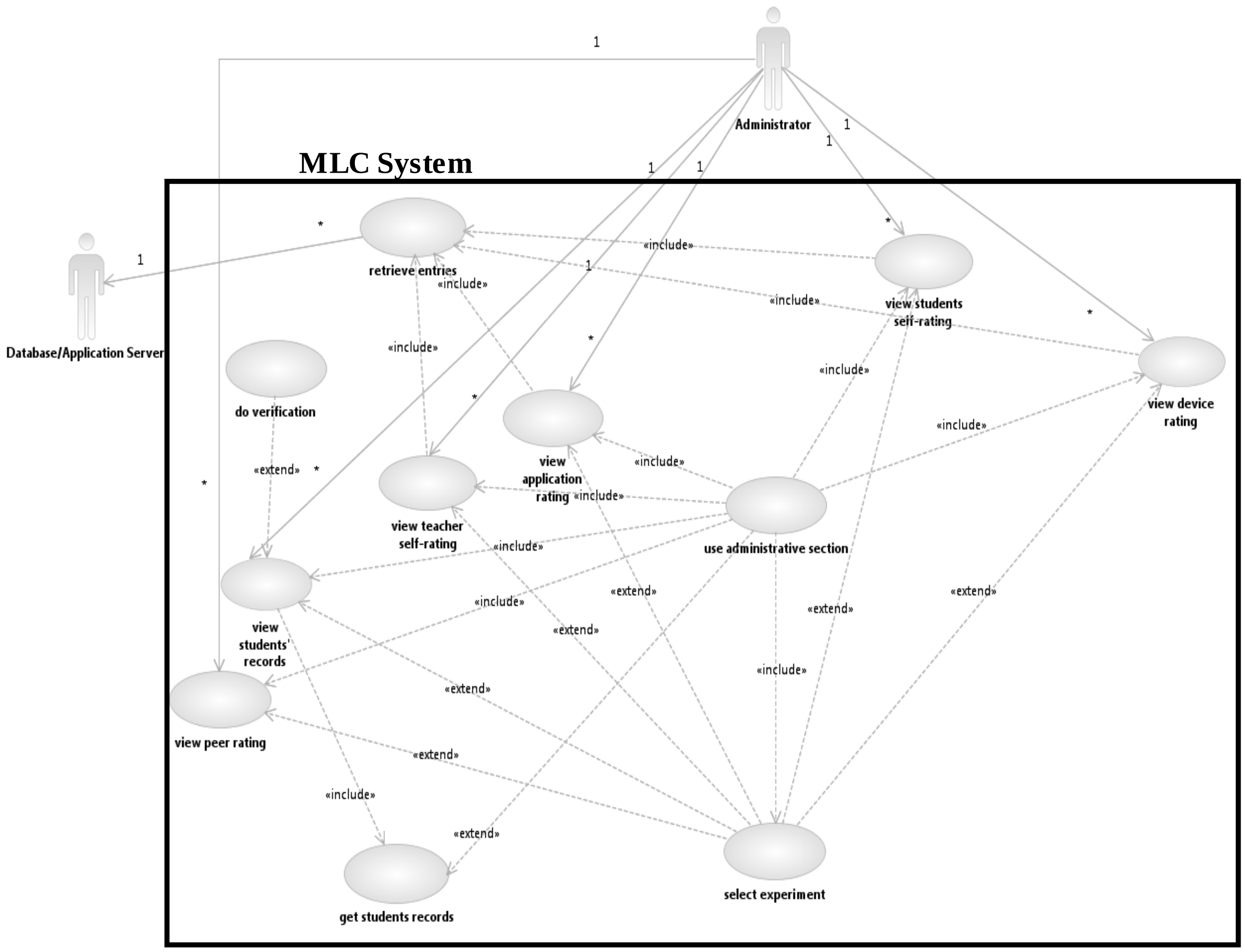

Figure 4.12: Actor-use case pairs depicting the use cases involving the actor "administrator". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author)

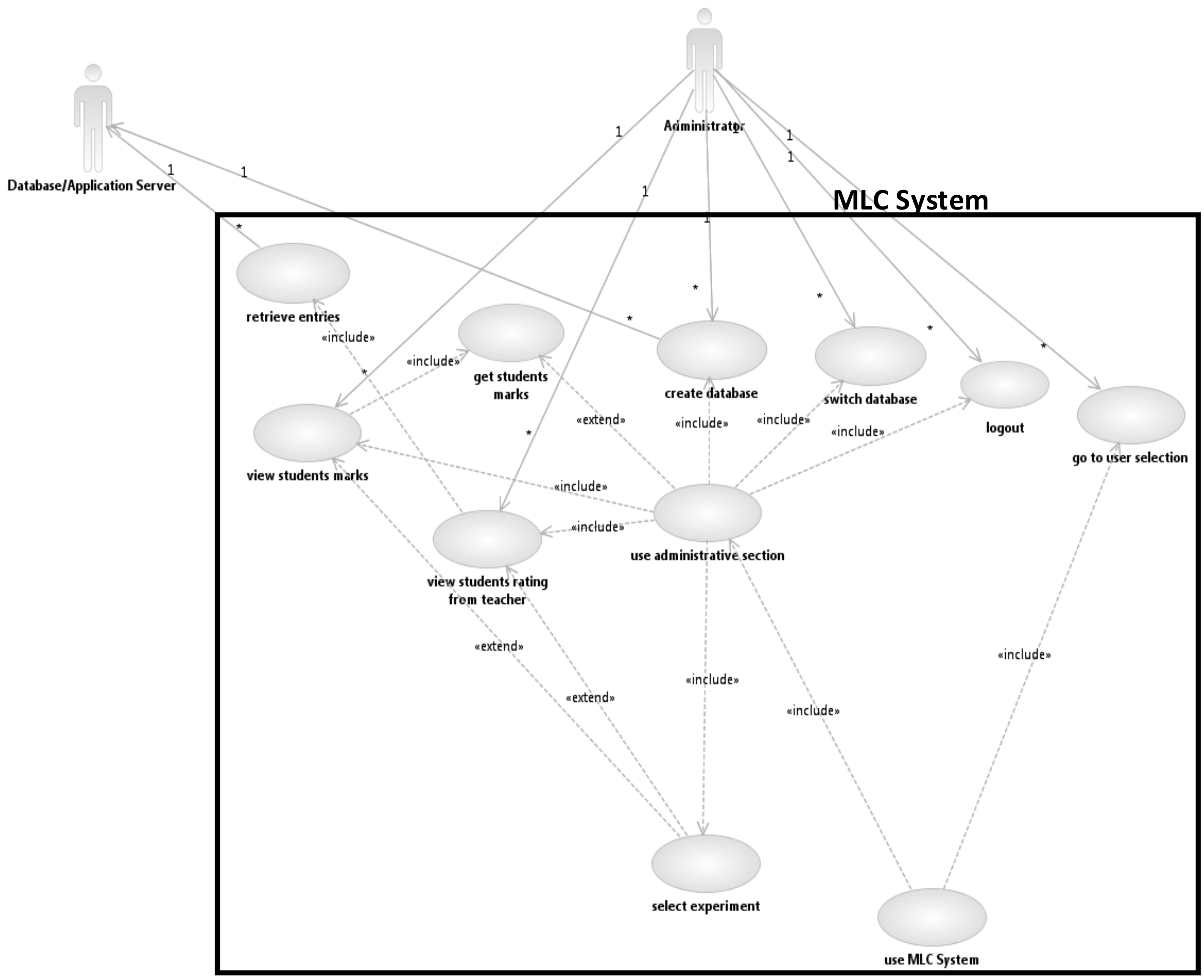

Figure 4.13: Actor-use case pairs depicting the use cases involving the actor "administrator". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author).

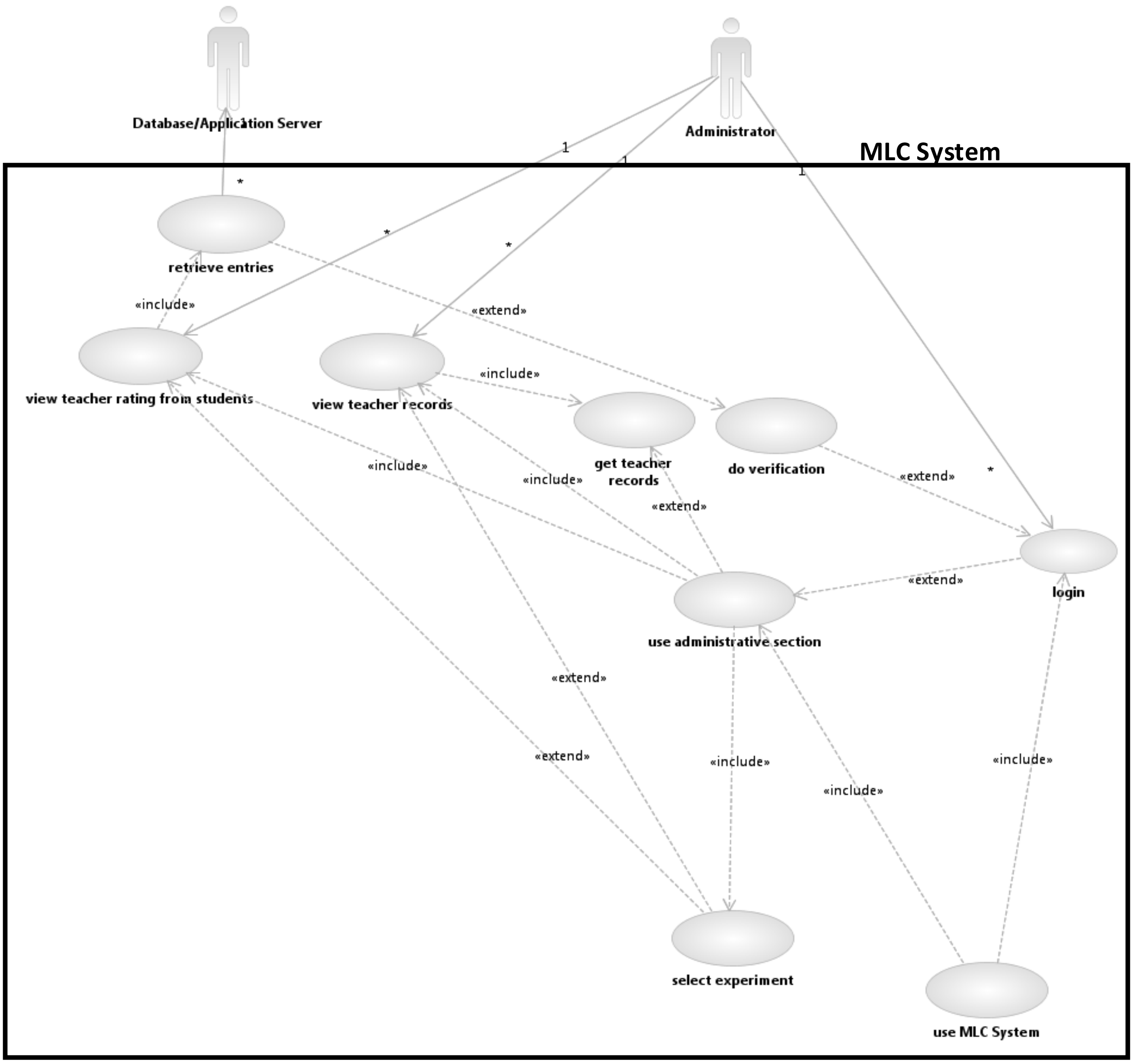

Figure 4.14: Actor-use case pairs depicting the use cases involving the actor "administrator". Diagram created using Rational Software Architect Standard Edition, V7.5.0 (Author).

Detailed information on the requirement analysis is in Appendix C. It contains all the use case analysis, the conceptual class diagrams, sequence diagrams and collaboration diagrams. The design is in Appendix D, which contains all the information about the necessary design classes (design class diagrams).

4.7 Conclusions

The application (MLC System) used in this research experiment was modularised for maintainability and debugging as suggested by Haas (2013) and Microsoft (2013), flexibility and easier extension in future use as suggested by Microsoft (2013). The GUI was designed considering some basic human factors (the presentation of information, the grouping of information, and information sequencing). Rapid Application Development (RAD) was employed for the development of the application to reduce the application development time by using CASE tools, to produce quick prototypes (screen layouts etc.) and also to encourage the users' feedback and make necessary changes where possible. The users' requirements were analysed and application design created based on the requirement specifications. These requirements and design specifications (documents) were created using the CASE tool Rational Software Architect, Standard Edition, V7.5.0.

The database used in the experiment for this research went in phase (hand in hand or concurrently) with the application development. It is discussed in the next chapter.

5. Designing the Experiment Part 2: Research Database

5.1 Introduction

This chapter discusses the database used in the experiment for this research. It covers the database life cycles used for the development of the database used for the experiment in this research. The name of the database is Math Learning Collaborator Database (MLCDB). It contains thirty-seven objects and was designed with the CASE tool called CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. The Erwin Data Modeller (evaluation version) only permits twenty-five objects per model, and as a result, the objects were modelled in two parts and then joined to realize the complete data model for the database used for experiment in this research. Note: The database development discussed in this chapter and the application development discussed in the previous chapter went synchronously.

Before going further to discuss MLCDB development used in the experiment for this research, some multiplicity symbols need to be shown with their meanings. [Note: This notation is Crow's Foot Version in information engineering]

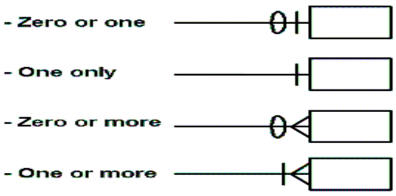

Figure 5.1a: Strong Relation Multiplicity Symbol (Image edited using paint image editor)

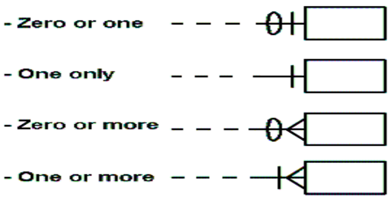

Figure 5.1b: Weak Relation Multiplicity Symbol (Image edited using paint image editor)

These symbols are used in this chapter for the database design.

5.2 *Experimental Rules for MLCDB*

In the business world, this term is called business rules, but since this is an empirical research in the educational sector, it is then termed experimental rules. With this in mind, the experiment required that data adhere to certain restrictions or rules. This rules which were implemented at the database level, and were actually enforced at the application level. An alternative to this enforcement is triggers, which were not used since the designers implemented the enforcement at the application level. The experimental rules are discussed under the following headings below.

- NOT NULL constraint
- Unique constraint
- Primary key constraint
- Foreign key constraint
- Check constraint
- Informational constraint

5.2.1 NOT NULL Constraints

This prevents null values from being entered into MLCDB's objects columns that are specified not to be null. It uniquely identifies each record in an MLCDB table.

5.2.2 Unique Constraints

This ensures that the values in a set of MLCDB table columns are unique and not null for all rows in the MLCDB tables or objects. A primary key constraint automatically has a UNIQUE constraint defined on it.

5.2.3 Primary Key Constraints

Each table in MLCDB has one primary key. This is a column or combination of columns that has the same properties as a unique constraint. This in addition with the foreign key constraints was used to define relationships between MLCDB tables. They were beneficial, because they ordered the data when data is reorganized.

5.2.4 Foreign Key Constraints

Foreign key constraints (also known as referential integrity constraints) enabled required relationships to be defined between and within MLCDB tables.

5.2.5 Check Constraint

This is the experimental rule that specified the values allowed in one or more columns of every row of an MLCDB table. This was not implemented at the data level, but was enforced at the application level e.g. the maximum number of students that can be contained in a class is 99.

5.2.6 Informational Constraints

This is a rule that was used by MySQL compiler but not enforced explicitly. The purpose of the constraint was to improve query performance. Informational constraints were defined using the CREATE TABLE or ALTER TABLE statements.

5.3 Ramifications of the Rules

The experimental rules resulted in the following relationships that were required for the experiment to be successful.

Teacher Side Relationships

- An experiment can be performed in one or more schools, but a school can only be involved in one experiment.
- An experiment can be conducted on one or more classes, but a class can only be involved in an experiment.
- One or more teachers can conduct an experiment, but a teacher can only be involved in an experiment.
- An experiment can be conducted on one or more groups of students, but a group can only be involved in one experiment.
- An experiment can include one or more tests but a test can be taken in one experiment.
- A teacher can teach only one class, and only one class can be taught by a teacher.
- A teacher can teach one or more strands, and a strand can be taught by one or more teachers.
- A strand can have one or more strand units, but a strand unit can only belong to a strand.
- A strand unit can have one or more topics, but a topic can only belong to a strand unit.
- A teacher can be involved in one teacher self-assessment, and only one teacher self-assessment can be conducted by a teacher.

- A teacher self-assessment can be conducted on zero, one or more teacher qualities, and a teacher quality can be included in zero, one or more teacher self-assessments.
- A comment can be made on zero, one or more teacher qualities and a teacher quality can have zero, one or more comments.
- A teacher can be involved in one teacher assessment, and only one teacher assessment can be conducted by a teacher.
- A teacher assessment can be conducted on zero, one or more teacher qualities, and a teacher quality can be included in zero, one or more teacher assessments.
- A teacher can have one device, and only one device can belong to a teacher.
- A device can be involved in one device assessment, and one device assessment can be only be conducted on a device.
- A device assessment can be conducted on zero, one or more device qualities, and a device quality can be included in zero, one or more device assessments.
- A comment can be made on zero, one or more device qualities and a device quality can have zero, one or more comments.
- A teacher can use one application copy, and one application copy can only be used by a teacher.
- An application copy can be involved in one artefact assessment, and one artefact assessment can be only be conducted on an application copy.
- An artefact assessment can be conducted on zero, one or more artefact qualities, and an artefact quality can be included in zero, one or more artefact assessments.
- A comment can be made on zero, one or more artefact qualities and an artefact quality can have zero, one or more comments.
- A teacher can have one login, and one login can only be used by a teacher.

Student Side Relationships

- An experiment can be performed in one or more schools, but a school can only be involved in one experiment.
- An experiment can be conducted on one or more classes, but a class can only be involved in an experiment.
- An experiment can include one or more tests, but a test can only belong to an experiment.
- A student can have one login, and one login can only be used by a student.
- A class can contain many students, but a student can belong to a class.
- A student can take one or more tests, and a test can be taken by one or more students.

- A test can have one or more questions, but a question can only belong to a test.
- A question can be answered by zero, one or more students, and a student can answer zero, one or more questions.
- A strand can have one or more strand units, but a strand unit can only belong to a strand.
- A strand unit can have one or more topics, but a topic can only belong to a strand unit.
- A group can learn one or more strands, strand units and topics, and a strand, strand unit and topic can be learnt by one or more groups.
- A group can contain one or more students, but a student can only belong to a group.
- A student can have one device, and a device can only belong to a student.
- A student can be involved in one formative assessment, and a formation assessment can only be conducted on one student.
- A formative assessment can be conducted on zero, one or more student qualities, and a student quality can only be involved in zero, one or more formative assessments.
- A self-formative assessment can be conducted on zero, one or more student qualities, and a student quality can only be involved in zero, one or more self-formative assessments.
- A peer formative assessment can be conducted on zero, one or more student qualities, and student quality can be involved in zero, one or more peer formative assessments.
- A group can have one or more devices, but a device can only belong to a group.
- A group can be involved in zero, one or more formative assessments, but a formative assessment can only be conducted on a group.
- A group can be involved in zero, one or more self-formative assessments, but a self-formative assessment can only be conducted on a group.
- A group can be involved zero, one or more peer formative assessment, but a peer formative assessment can only be conducted on a group.
- A comment can be made on zero, one or more student qualities, and student quality can be involved in zero, one or more comments.

Administrator Side Relationships

- An administrator can have one login, and a login can only belong to an administrator.

5.4 Database Life Cycles (DLC) used

Five stages of DLC were used for MLCDB. The stages are:

- Database planning

- Requirement collection and analysis
- Database design
- Implementation
- Testing

[Note: The testing phase is included in Appendix E. It covers the application/database testing]

5.4.1 Database Planning

In this phase, approaches on how to gather or collect necessary information from the users (Presentation Primary School students and teacher), the format specification of the information, necessary documentation for the design and development of the database were carefully developed e.g. interviews were planned with necessary questions that allow relevant information to be gathered etc.

5.4.2 Requirement Collection and Analysis

Users' requirements were collected from the users of the system (Presentation Primary School students and teacher), and then analysed. These requirements came from the user views of the system. The approach used in this phase is called view integration approach in which the requirements for each user view were used to build a separate data model called local data model. The local data models are then merged together to create a global data model which represents all user views of the database (MLCDB). For the sake of excessive information, the requirement analysis is omitted from this research but can be easily noticed via the design. With this in mind, the teacher conceptual, logical and physical local data model will be discussed first, followed by the students and then the administrator.

5.4.3 Design

MLCDB design, which is the process of modelling the database (MLCDB) that supported the experimental execution and objectives, is discussed here.

5.4.3.1 Data Models for Teacher User view

The data models for the teacher user view are shown here. These resulted from the requirements of the teacher user view for MLCDB. The teacher user view's conceptual data model is shown in figure 5.2.

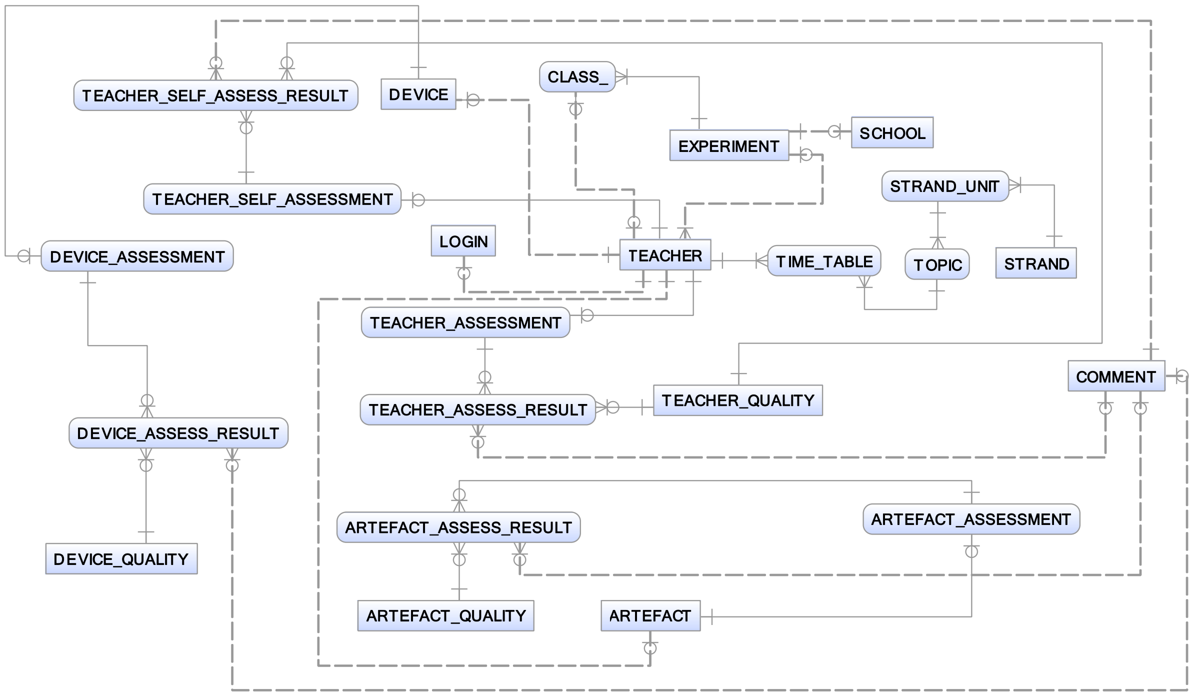

Figure 5.2: Local Conceptual Data Model for Teacher User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.3 is the local logical data model for the teacher user view.

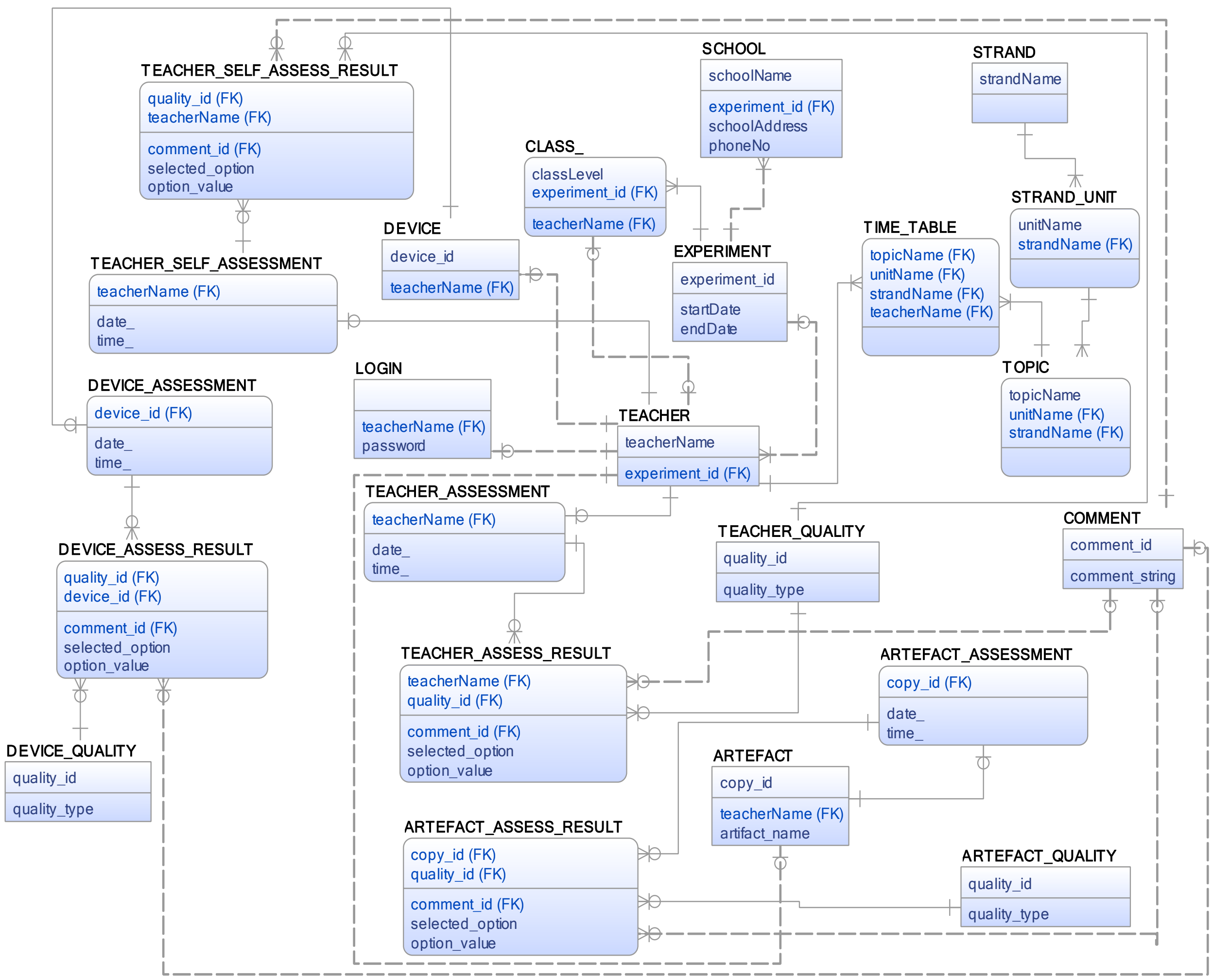

Figure 5.3: Local Logical Data Model for the Teacher User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.4 is the local physical data model for the teacher user view.

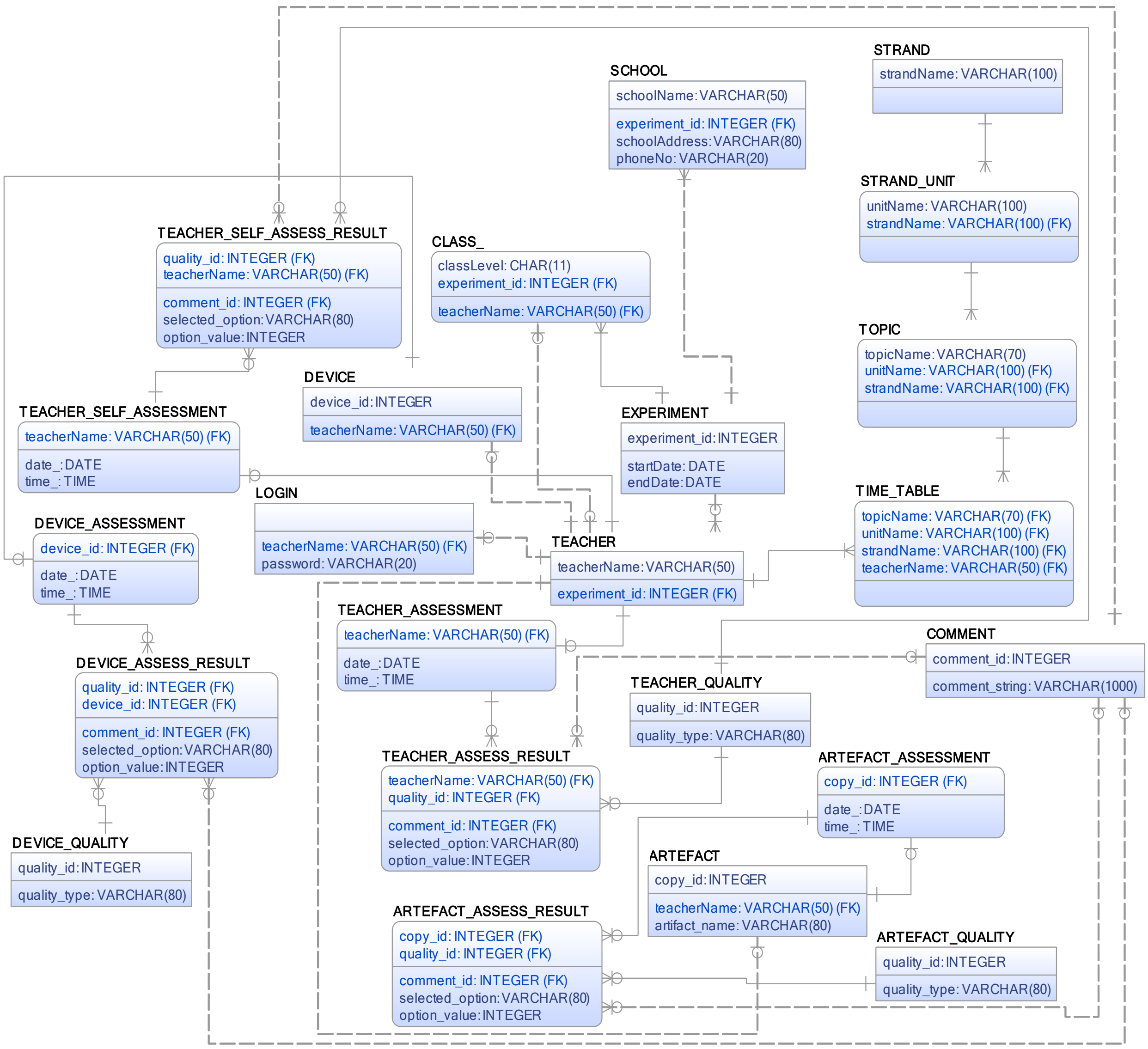

Figure 5.4: Local Physical Data Model for the Teacher User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

5.4.3.2 Data Models for Student User View

The data models for the student user view are shown here. These resulted from the requirements of the student user view for MLCDB. The diagram is broken into two due to the 25-object limitation of Erwin Data Modeler. Each two diagrams complete a model for student's user view of MLCDB. Shown in figure 5.5a is the conceptual data model for the student user view. This is completed in figure 5.5b. [Note: Only five more objects were added in figure 5.5b to complete the model]

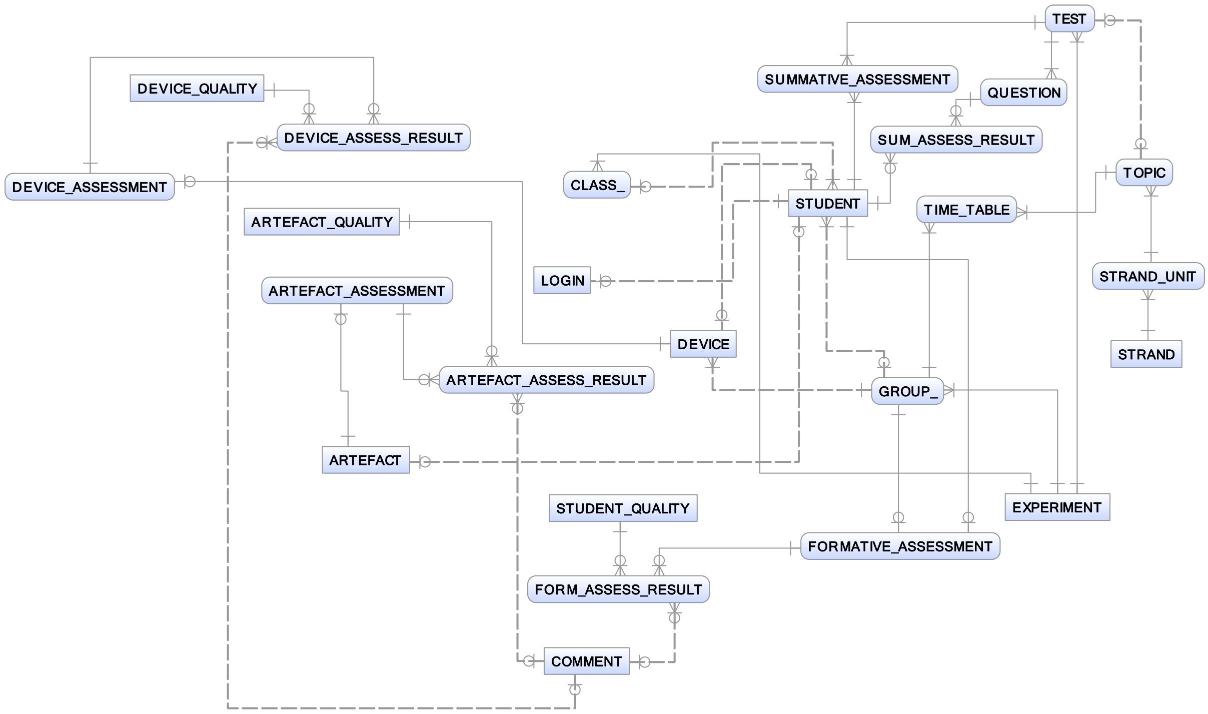

Figure 5.5a: Local Conceptual Data Model for Student User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

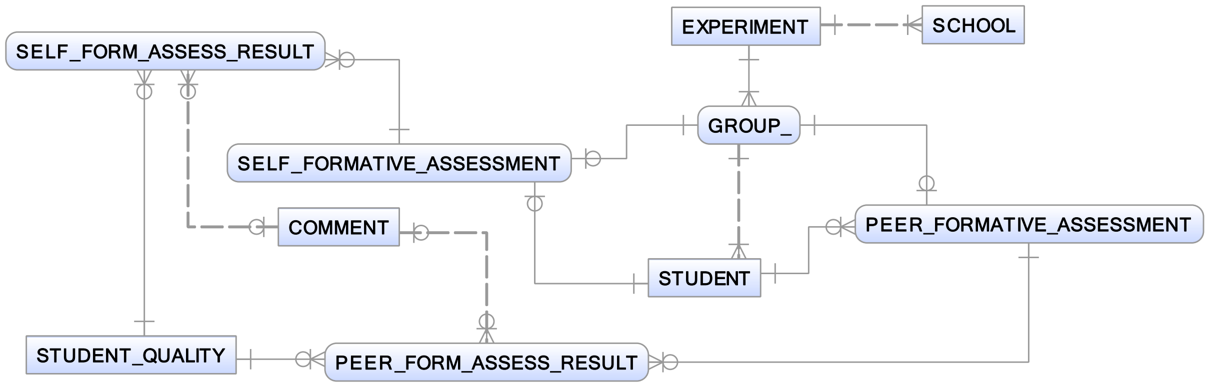

Figure 5.5b: Local Conceptual Data Model for Student User View (completing figure 5.5a). Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.6a is the local logical data model of the student user view. This was realized from the model in figure 5.5a.

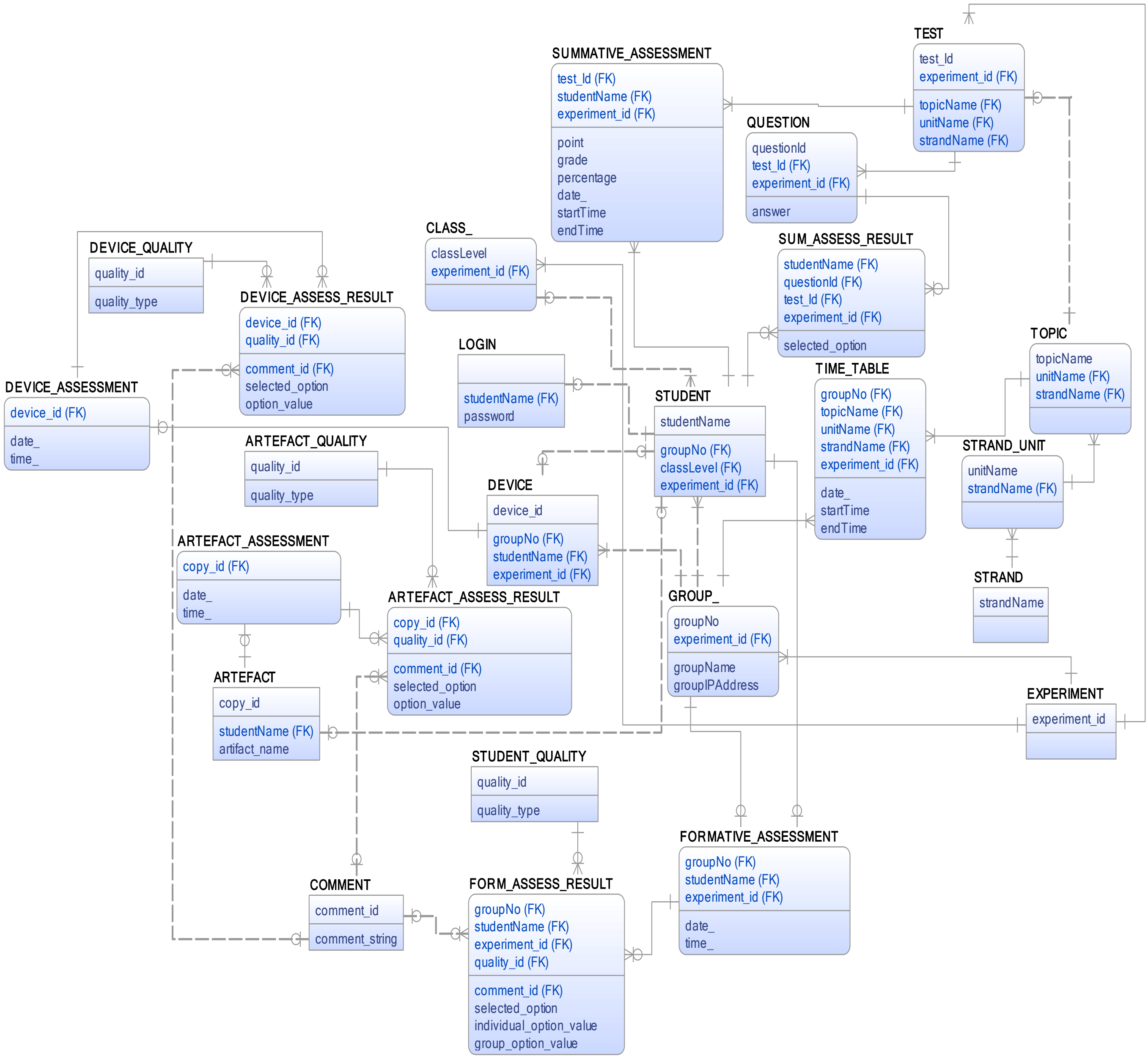

Figure 5.6a: Local Logical Data Model for Student User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.6b is the local logical data model of the student user view. This was realized from the model in figure 5.5b, and completes the logical model in figure 5.6a.

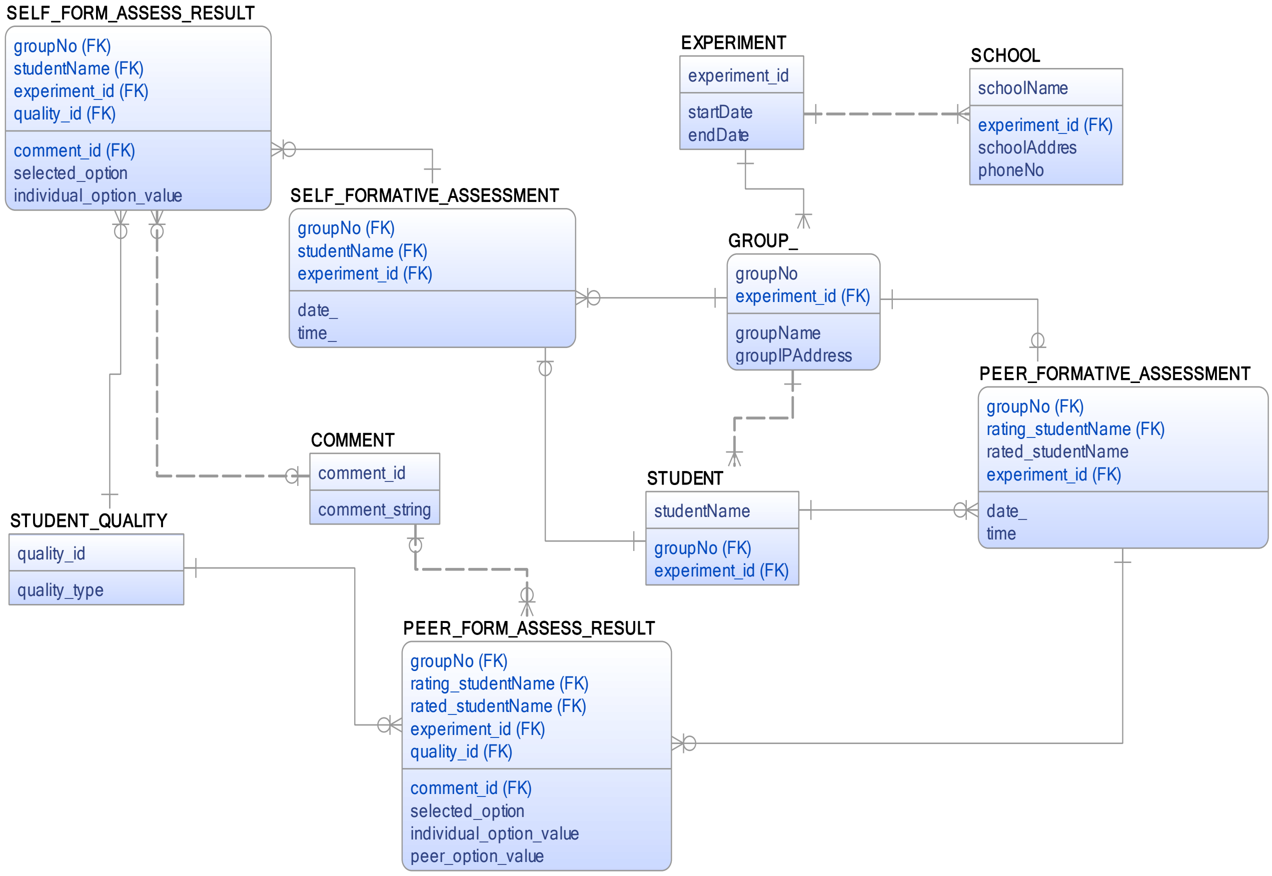

Figure 5.6b: Local Logical Data Model for Student User View (completing figure 5.6a). Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.7a is the local physical data model of the student user view. This was realized from the model in figure 5.6a.

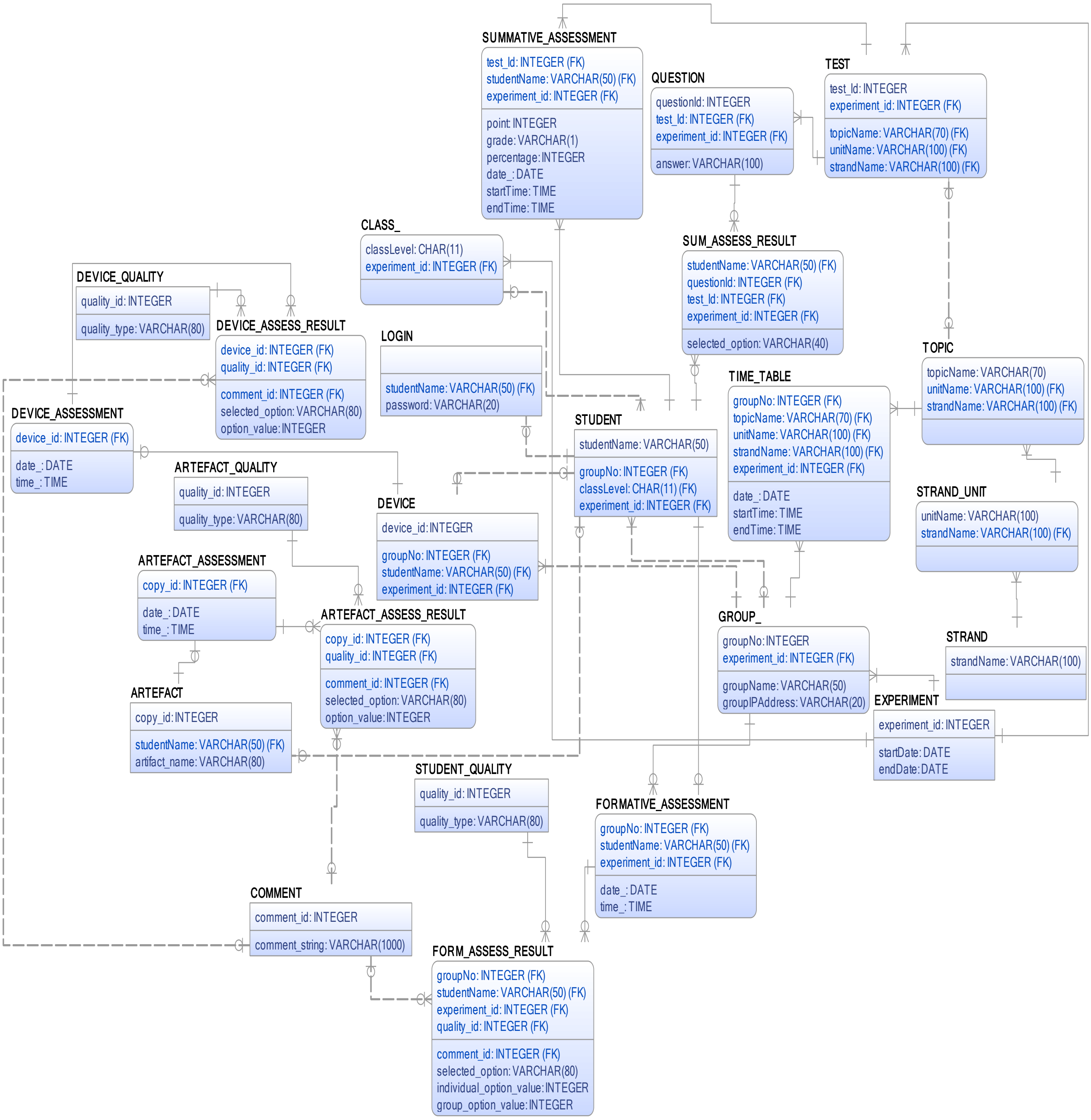

Figure 5.7a: Local physical data model for student user view. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.7b is the local physical data model of the student user view. This was realized from the model in figure 5.6b, and completes the model in figure 5.7a.

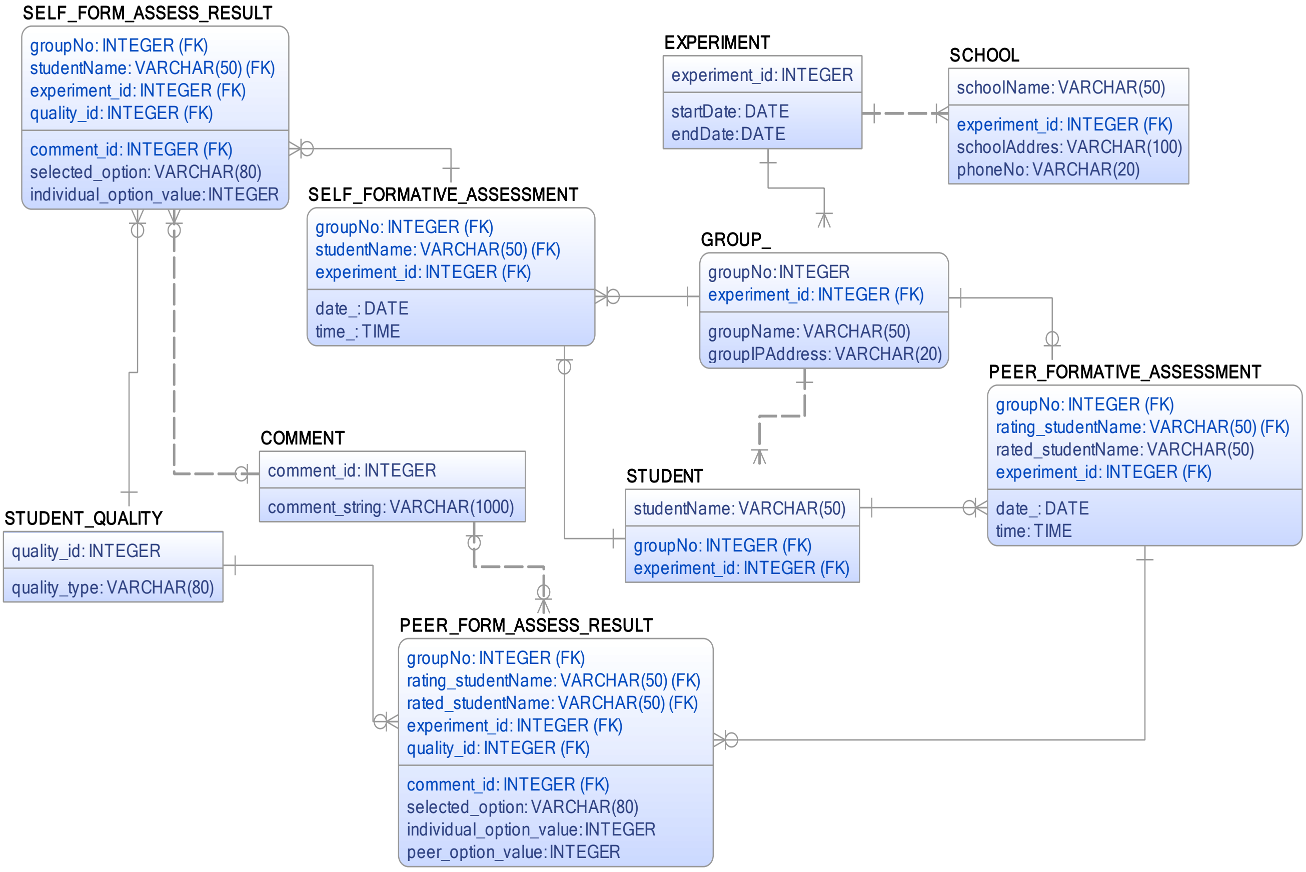

Figure 5.7b: Local Physical Data Model of the Student User View (completing figure 5.7a). Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

5.4.3.3 Data Models for Administrator User View

The data models for the administrator user view are shown here. These resulted from the requirements of the administrator user view for MLCDB. The administrator data models only has two entities. This was for the fact that the administrator is not part of the experiment execution but for the evaluation and maintenance e.g. viewing results, creating database etc., which resulted in the administrator not having any relationship and connection with the entities except the two entities that are modelled here. Shown in figure 5.8 is the local conceptual data model of the administrator user view.

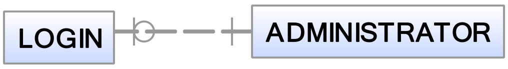

Figure 5.8: Local Conceptual Data Model of the Administrator User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.9 is the local logical data model of the administrator user view.

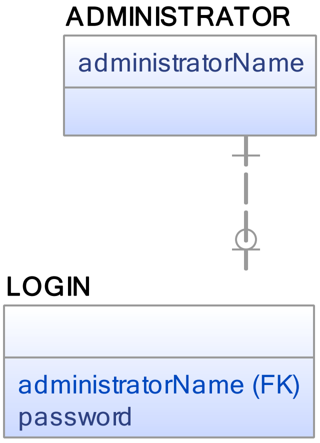

Figure 5.9: Local Logical Data Model of the Administrator User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

Shown in figure 5.10 is the local physical data model of the administrator user view.

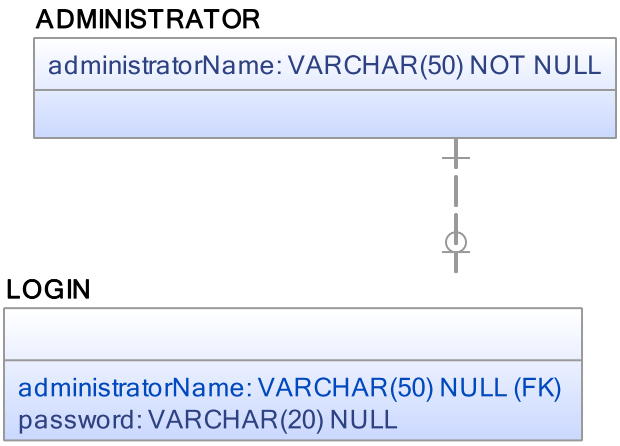

Figure 5.10: Local Physical Data Model of the Administrator User View. Diagram created using CA Erwin Data Modeler, Community Edition, Release 9.2.00.3957. (Author)

5.4.3.4 Global Data Models for all User View

The global data model for the entire user views is shown here. These resulted from merging all the local data models that represent the requirements of the entire user views for MLCDB. Shown in figure 5.11 is the global conceptual data model for all the user views for MLCDB, which consists of thirty seven entities. Colours were used to create distinctions between lines where appropriate for easier view.

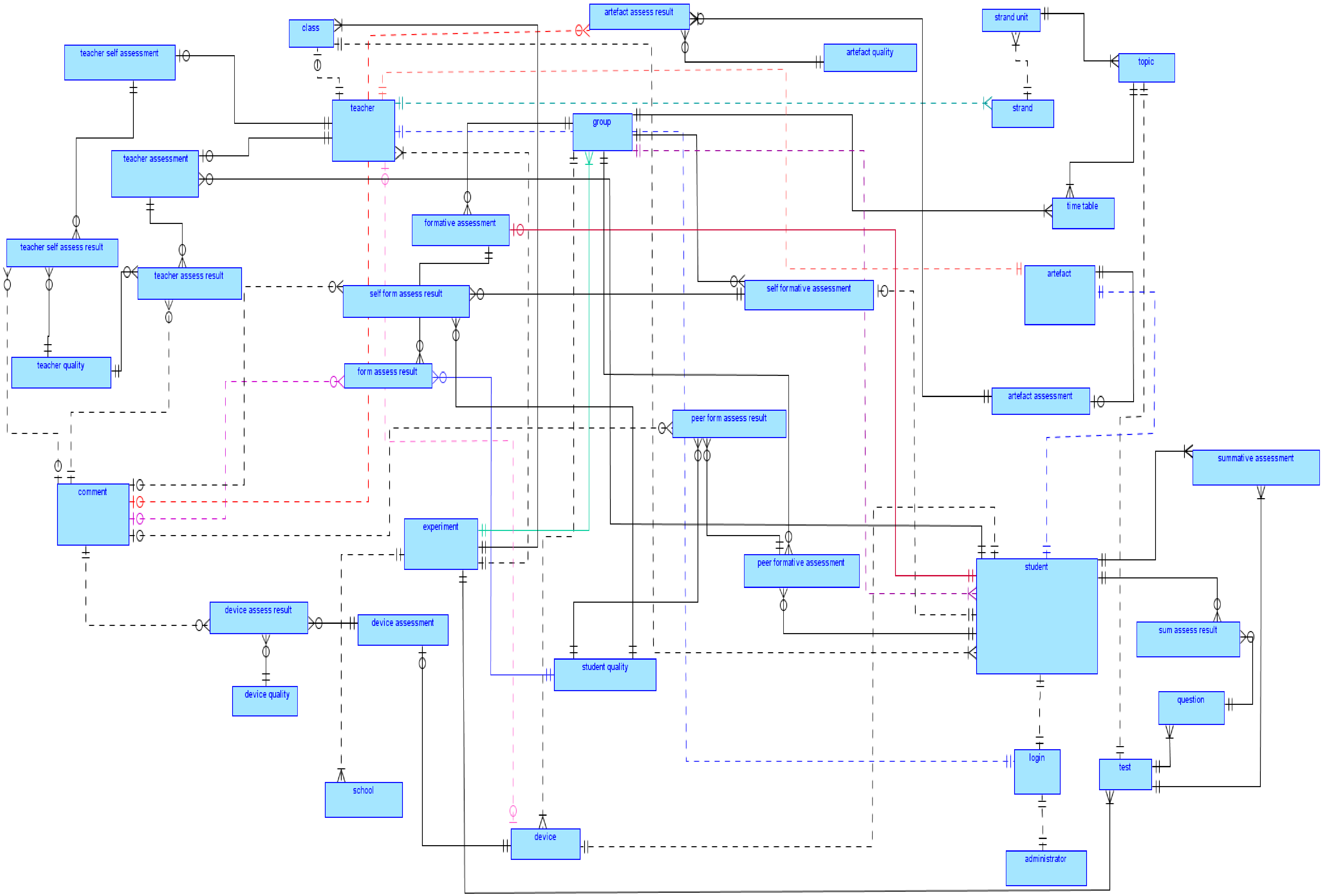

Figure 5.11: Global Conceptual Data Model of All User Views. Diagram created using Oracle SQL Developer Data Modeler, V3.3.0.747. (Author)

Shown below in figure 5.12 is the global logical data model for all the user views for MLCDB, which consists of thirty seven entities. Colours were used to create distinctions between lines where appropriate for easier view.

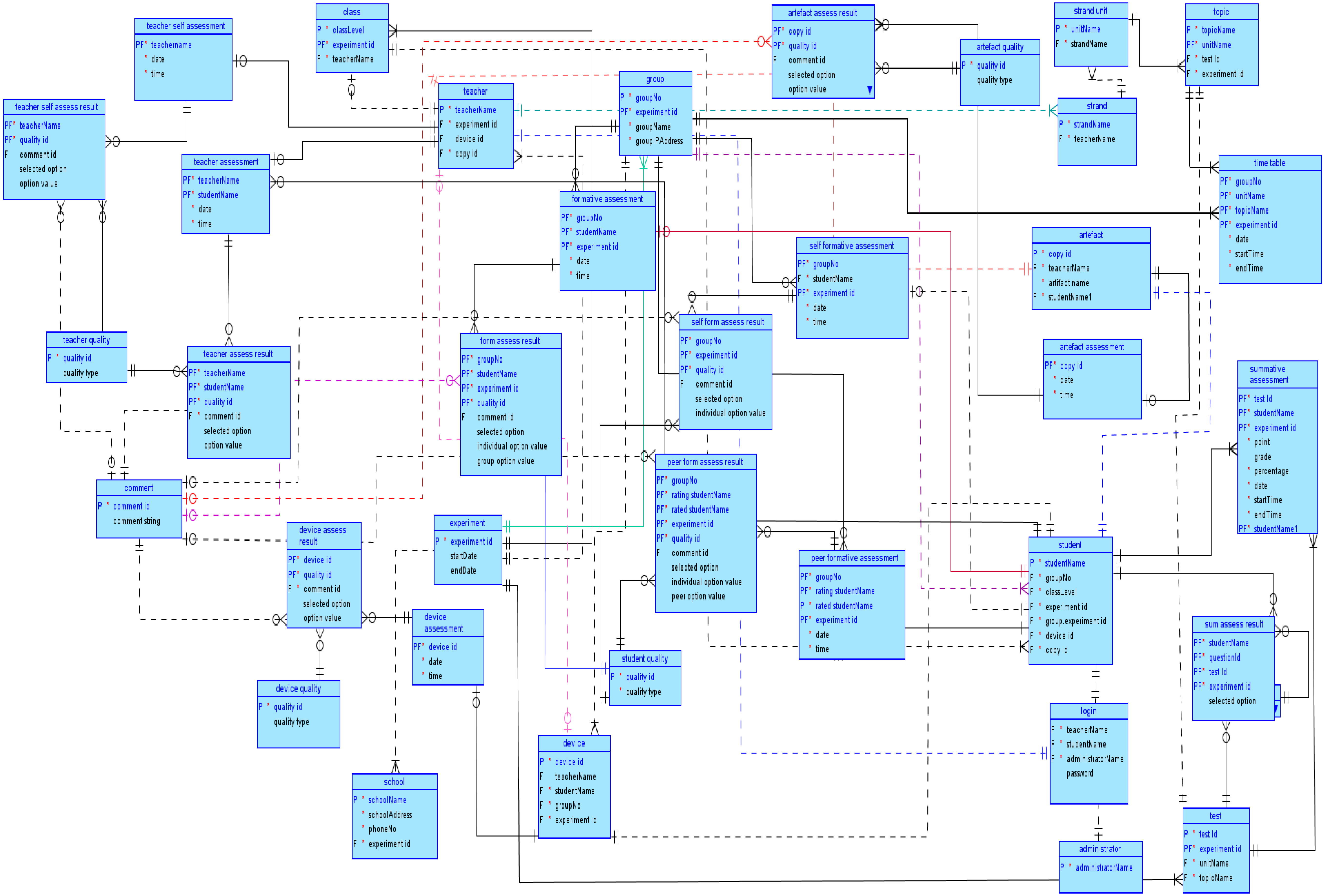

Figure 5.12: Global Logical Data Model of All User Views. Diagram created using Oracle SQL Developer Data Modeler, V3.3.0.747. (Author)

Shown below in figure 5.13 is the global physical data model for all the user views for MLCDB, which consists of thirty seven entities. Colours were used to create distinctions between lines where appropriate for easier view. [Note: The original relational model was not used since it contains more information that will increase the complexity of the model view. Thus, in order to reduce the complexity in understanding the model, only the primary/foreign key constraint was added as shown. The null/not null and informational constraint and indexes can be referenced (in script.sql contained in a folder called MLC DDL Script) in appendix H of this research]

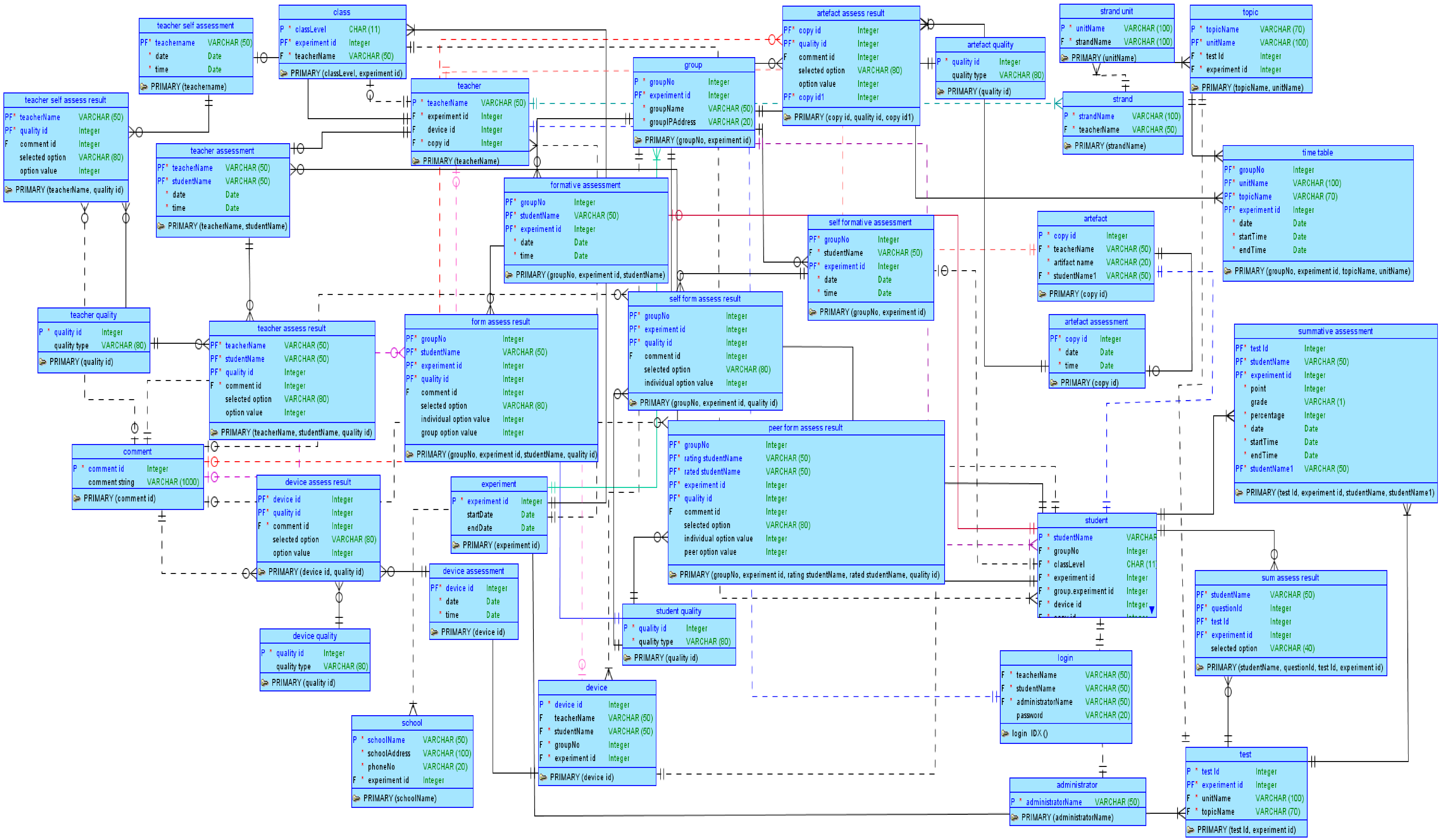

Figure 5.13: Global Physical Data Model of All User Views. Diagram created using Oracle SQL Developer Data Modeler, V3.3.0.747. (Author)

5.4.4 Implementation

The database (MLCDB) was physically realized by using Data Definition Language (DDL) to create database schemas and empty database files, user views, external schema and physical/storage schema based on the design considerations. [Note: For more information on the implementation, refer to the DDL (in script.sql) in appendix H of this research paper. The testing for the database and the application is included in appendix E]

5.5 Conclusions

The database (MLCDB) used in the experiment for this research was developed by planning ahead on how to elicit the requirements, and then collecting and analysing the teacher, student and administrator user views via the approach of view integration. The results of the analysis (requirement specification) for each user view were then modelled locally and then merged to realize the global data model for the user views. This was then implemented on the physical machine using DDL.

With this in mind, the experiment for this research was conducted on sixteen primary school students and a teacher, and the results were evaluated to either proof or disproof the hypotheses raised in the research questions. This is discussed in the next chapter.

6 Experimentation and Evaluation

6.1 *Introduction*

This chapter looks at how the experiment was prepared, how it was executed, the composition of respondents, the evaluation of the results from the experiments and key findings from these results of the evaluation. The experiment performed for this research lasted three weeks starting from 10th June 2013 to 28th June 2013. It was conducted on sixteen fourth-class primary school students from Presentation Primary School. It was conducted similarly to the ones performed in Healy (2010) and Linchevski and Kutscher (1999). All the materials used in this experiment conformed to the Irish Primary School Math Curriculum (1999).

6.2 *Experiment Preparation*

The preparation of the experiment was conducted for six days, starting from 10 June 2013 and ending on 17 June 2013. It involved given sixteen fourth-class primary school students some mathematics pre-lessons and pre-tests in nine topics (see appendix I for the pre-lessons and pre-tests). These topics were selected from three strand units, and the strand units from two strands. This is shown in table 6.1.

Strand	Strand Unit	Topics	Date
Shape and Space	2-D Shapes	Quadrilaterals	10/06/13
		Triangles	11/06/13
		Polygons	12/06/13
	3-D Shapes	3-D Properties	13/06/13
		Regular Polyhedrons	13/06/13
		Non-Polyhedrons	14/06/13
Measures	Time	Clock	14/06/13
		Time Addition/Subtraction	17/06/13
		Time Conversion/Calculation	17/06/13

Table 6.1: Experiment Pre-Lessons and Pre-Tests Time Table Outline. (Author)

Table 6.1 shows when the topics were taken during the experiment preparation, and to which strand units and strands the topics belonged. The results from these mathematics pre-tests (given to the students before applying the treatment) were used for further justification of the analysis (in section 6.5.1) by comparing them to the post-test results. The sixteen students were then grouped according to their pre-test performance as discussed in the next section.

6.2.1 Experimental Group Arrangement

The sixteen students selected for the experiment were divided into four groups. Each group consisted of four students. The first and second group were the heterogeneous groups consisting of two high-ability students and two low-ability students each. The third group was the homogeneous group consisting of four low-ability students. The fourth group was the separated group consisting of four low-ability students. This is shown in table 6.2.

Group Arrangement							
Group 1 (heterogeneous group)		**Group 2** (heterogeneous group)		**Group 3** (homogeneous group)		**Group 4** (separated group)	
Ability Type	**Student Names**	**Ability Type**	**Student Names**	**Ability Type**	**Student Names**	**Ability Type**	**Student Names**
High-ability	Bichon, Rose of Trolee	High-ability	dog lover 123, dolphin 9	Low-ability	msclever, smartbrain, snowleopard, tigerlily	Low-ability	brainbuster, galaxy, mars 123, redrose
Low-ability	dog lover, Superdog 123	Low-ability	blue rose, smartcelt				

Table 6.2: Experimental Group Arrangement with Student Names. (Author)

As shown in table 6.2, the student has been resolved into their respective ability groups. These groups were formed based on the students' pre-tests results. In addition, each low-ability student in the heterogeneous groups was linked or tied to a low-ability student in the homogeneous group and a low ability student in the separated group at random so that any differences between and within the treatment groups (heterogeneous) and control groups (homogeneous and separated) are not systematic at the outset of the experiment. In addition, this was done in order to verify whether there would be a huge or negligible difference between the scores of a particular student in the heterogeneous group and the corresponding (linked) student in the homogeneous group or separated group. The tie or link between the students is shown in table 6.3.

Heterogeneous Group	Homogeneous Group	Separated Group
dog lover	msclever	brainbuster
Superdog 123	smartbrain	galaxy
blue rose	snowleopard	mars 123
smartcelt	tigerlily	redrose

Table 6.3: Students' Link Table from Different Groups. (Author)

[Note: Students on the same column are tied together]

The devices that were used for the experiment were then configured into four groups accordingly as discussed in the next section.

6.2.2 Experiment Devices' Network Topology

There were seventeen laptops involved in the experiment. Sixteen of those belonged to the students and the remaining one belonged to the teacher. The students' sixteen computing devices were separated into four broadcast domains. Each broadcast domain contains four computing devices as shown in figure 6.1.

As shown in figure 6.1, the teacher used the central application/database server as her device, which could transmit information to and receive information from the student devices. The student devices were separated into four broadcast domains. The broadcast domains for the heterogeneous and homogeneous groups used adhoc setting while the separated group were not connected to each other. This simply means the students in heterogeneous and homogeneous groups could communicate with each other, but the student in the separated group could not. The diagram in figure 6.1 just depicted the class setting for the experiment.

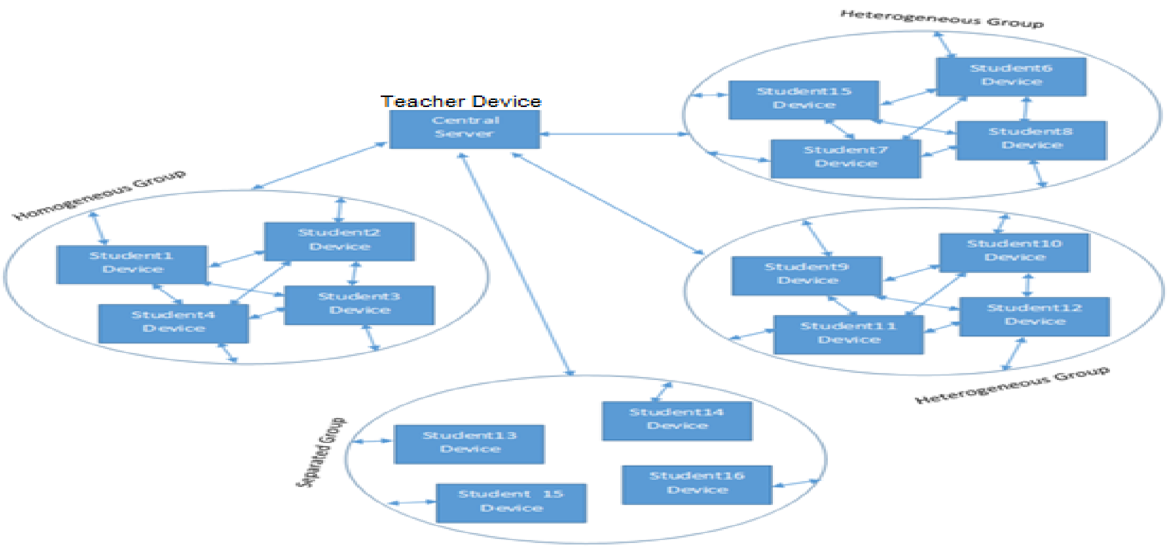

Figure 6.1: Experimental Device Network Topology. (Author)

The execution of the experiment was then carried out as will be discussed in the next section.

6.3 Experiment Execution

The execution of the experiment lasted for nine days, starting from 18 June 2013 and ending on 28 June 2013. It involved given the sixteen students some mathematics post-lessons and post-tests in nine topics (see appendix J for post-lessons and post-tests). These topics were selected from three strand units, and the strand units from two strands. Sixteen students that were shown in the previous section (section 6.2.1) were involved in this experiment execution. The execution outline is shown in table 6.4.

STRAND	STRAND UNIT	TOPICS	DATE
Shape and Space	2-D Shapes	Quadrilaterals	18/06/13
		Triangles	19/06/13
		Polygons	20/06/13
	3-D Shapes	3-D Properties	21/06/13
		Regular Polyhedrons	24/06/13
		Non-Polyhedrons	25/06/13
Measures	Time	Clock	26/06/13
		Time Addition/Subtraction	27/06/13
		Time Conversion/Calculation	28/06/13

Table 6.4: Experiment Execution Outline. (Author)

Table 6.4 shows when the topics were taken during the experiment execution, and to which strand units and units the topics belonged.

The experiment adopted theories of learning and instructional design, as discussed in the literature review, during its execution. In terms of behaviourism, the students' learning outcome was controlled via stimuli such as formative assessment characteristics e.g. group work attitude, communication etc. In terms of cognitivism, the students were allowed to create knowledge via interaction (chatting with each other) and use their cognitive power to understand meaning of expressions and figures, and in terms of constructivism, the students were allowed to construct knowledge based on their mental ability by doing some pre-test exercises progressively and drawing some collective conclusions. The teacher employed Montessori's three periodic lessons for the students in which she provided the materials for the students, help them understand different geometric shapes and confirm by asking them some questions to know if they have understood what they were. Montessori's second plane of development was employed in the experiment since the students were between 6 - 12 years. The teacher used the Gagne's nine events of instruction to foster learning to the students. This in addition was implicitly inherent in the application used by the students. Information processing theory was employed by using images to reinforce and recall knowledge for the students in which connections between new and prior knowledge were made. Elaboration theory was employed in the experiment execution by starting with simplest ideas, in the first lesson, and then add elaborations in subsequent lesson, and finally, ICARE model was considered in organising the learning content used in the experiment.

The respondents for the research were categorised under several headings in order to resolve them and know the amount of information issued and the amount returned. This is discussed in the next section.

6.4 Composition of Respondents

Shown in table 6.5 is the composition of respondents. This table shows the amount of assessments results retrieved or returned for a corresponding amount of assessments sent or issued.

<table>
<tr><th colspan="2">NUMBER OF ASSESSMENTS ISSUED</th><th colspan="2">NUMBER OF ASSESSMENTS RESULTS RETRIEVED OR RETURNED</th></tr>
<tr><td rowspan="2">Summative Assessments</td><td>144 Pre-tests</td><td colspan="2" rowspan="2">288</td></tr>
<tr><td>144 Post-tests</td></tr>
<tr><td rowspan="3">Formative Assessments</td><td>16 Formative assessments by teacher</td><td colspan="2" rowspan="3">68</td></tr>
<tr><td>16 Self-formative assessments</td></tr>
<tr><td>36 Peer formative assessments</td></tr>
<tr><td>16 Teacher assessments by students</td><td></td><td colspan="2">16</td></tr>
<tr><td>1 Teacher-self assessment</td><td></td><td colspan="2">1</td></tr>
<tr><td>17 Device assessments</td><td></td><td colspan="2">17</td></tr>
<tr><td>17 Artefact assessments</td><td></td><td colspan="2">17</td></tr>
<tr><td>17 Follow-up interviews</td><td></td><td colspan="2">9</td></tr>
<tr><td></td><td></td><td>Total = 416</td><td>Total (%) = 98%</td></tr>
</table>

Table 6.5: Composition of Respondents. (Author)

As shown in table 6.5, the study yielded 98% response rate, which is good for the evaluation stage. The results from the experiment are included in appendix F. For more information on all results captured on the screen, see appendix G.

6.4.1 Some Feedback from Interviews

After the experiment was completed a follow-up series of interviews were conducted with both the teacher and some of the students. The goal of which was to explore their reaction to the MLC system. A student commented, "*I got to learn about learned 2-D and I got to learn about 3-D shapes at times*" in the MLC with the help of the laptop and the application that allowed me to chat. Another student commented, "*It was helpful to me to know the size of the shape and the name*". Another commented that the experiment helped her know how to pronounce the shapes properly which she did not know before. Some commented that the experiment helped them because they have a subject called mental maths that was directly related to the experiment, and they have learnt how to understand shapes via vertices and edges in the subject through the experiment. They commented that their collaborative effort helped them realize their goals, and finally that they hope continuing in this type of study. The teacher commented that the images and graphics were child friendly and the chat feature was helpful in relating to the students. She commented, "*the text was easily read by the children particularly since comic sans font was used, which is often used for children*", and the automated marking system allowed for monitoring of students' progress. She commented, "*The program covered fourth-class material so was relevant to the children",* and that the students were able to collaborate in groups, especially the heterogeneous groups in which the less able students benefitted from the more able students and the children constructed their own meanings making the learning a constructive learning. She commented that the experiment lead to success in the students' performance, especially, those in the heterogeneous groups, and participation in the process of the study leads to many unexpected outcome that will benefit the student in the long term. She finally commented that if children are to participate successfully in the information age they must be practiced in learning, unlearning and relearning of the content delivered through digital media such as the one delivered in the study. For more information, see appendix K and L.

6.5 Evaluation of Results

The experiment results are analysed here to address the research questions. This is where the power of statistics comes to play. There are six research questions to be addressed, and each has two hypotheses (null and alternative hypothesis). In order to simplify this analysis, the research questions will be addressed one after the other by analysing the results necessary for that research question in order to verify whether the result of the analysis meet the hypothesis of the research question or not. Values are rounded to one decimal place to avoid too many fractional digits.

<u>Researcher Question 1</u>

Using the MLC, will there be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken?

- Null hypothesis 1 – *Using the MCL, there will be no significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*
- Alternative Hypothesis 1 - *Using the MCL, there will be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*

This question requires only the post-test results of the low-ability students in the heterogeneous and homogeneous groups to be analysed. This leads to the following results with their means (averages) in table 6.6, where μ is the mean or average post-test scores for the students.

Student groups	Student names	Post-Test Scores (%)									μ (%)
Heterogeneous group (HT)	dog lover	70	85	90	95	95	90	100	95	100	91.1
	Superdog 123	65	90	95	95	95	95	100	90	100	91.7
	blue rose	70	80	85	85	95	85	100	95	100	87.8
	smartcelt	65	75	80	90	90	85	100	95	95	86.1
Homogeneous group (HM)	msclever	55	60	55	60	45	55	50	50	65	55
	smartbrain	50	60	55	55	65	50	55	50	60	55.6
	snowleopard	60	65	60	60	50	45	60	50	65	57.2
	tigerlily	50	50	55	45	60	55	65	55	70	56.1

Table 6.6: Post-test scores of the low-ability students in heterogeneous and homogeneous groups with the averages. (Author)

Further Analysis of the outcome in table 6.6 further leads to the outcome in table 6.7.

Post-test scores' averages (%)								$\mu_{average}$	δ
91.1	91.7	87.8	86.1	55	55.6	57.2	56.1	72.6	17

Table 6.7: Differences between the means of the post-test scores of the students in the heterogeneous and homogeneous groups. (Author)

[Note: $\mu_{average}$ is the mean of the averages of the post-test scores, and δ is the standard deviation of these averages]

The outcome in table 6.7 is represented in a bar chart as shown in figure 6.2.

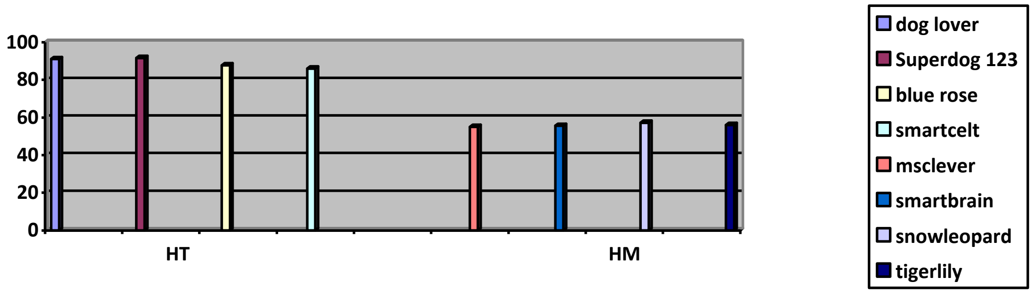

Figure 6.2: Bar chart depicting the variations (differences) between the means of the post-test scores of the students in the heterogeneous and homogeneous groups. (Author)

[Note: The first four plots represent the average post-test scores of the students in the heterogeneous group and the last four plots represent those of the homogeneous groups. The names of the students are shown on the right with colours of their plots]

As shown in the bar chart in figure 6.2, the average post-scores of the first two students in the heterogeneous groups are a little more than one standard deviation, 17, above the average mean ($\mu_{average}$) while those of the last two students in the heterogeneous groups are a little less than one standard deviation above $\mu_{average}$. The average post score of the first student in the homogeneous group is a little more than one standard deviation below $\mu_{average}$. That of the second student is just exactly one standard deviation below $\mu_{average}$. Those of the last two students in the homogeneous group are a little less than one standard deviation below $\mu_{average}$. Thus, the outcome of the analysis, presented on the bar chart in figure 6.2 satisfies the alternative hypothesis of research question 1.

The nature of this outcome depended on the average formative, average artefact, average device and average teacher assessment results. The averages of these assessment results are presented in table 6.8 and the plots is shown in the histogram of figure 6.3. The first four plot blocks represent those of the heterogeneous groups and the last four plot blocks represent those of the homogeneous group. The average formative assessment result (AFAR) for a student in either heterogeneous or homogeneous group is the average of the student formative assessment results by the teacher, peer formative and self-formative assessment results. The average teacher assessment results (ATAR) is the average of the teacher assessment results by a student and teacher self-assessment results. For the indication of AAAR and ADAR, see the note below figure 6.3.

Group	Student names	AFAR	AAAR	ADAR	ATAR
Heterogeneous Group (HT)	dog lover	4.5	5	5	5
	Superdog 123	4.6	5	5	5
	blue rose	4.5	5	5	4.9
	smartcelt	4.6	5	5	5
Homogeneous Group (HM)	msclever	3.5	5	5	5
	smartbrain	3.9	5	5	5
	snowleopard	3.9	5	4.7	4.9
	tigerlily	3.7	5	5	5

Table 6.8: Averages of assessment results in percentages. (Author)

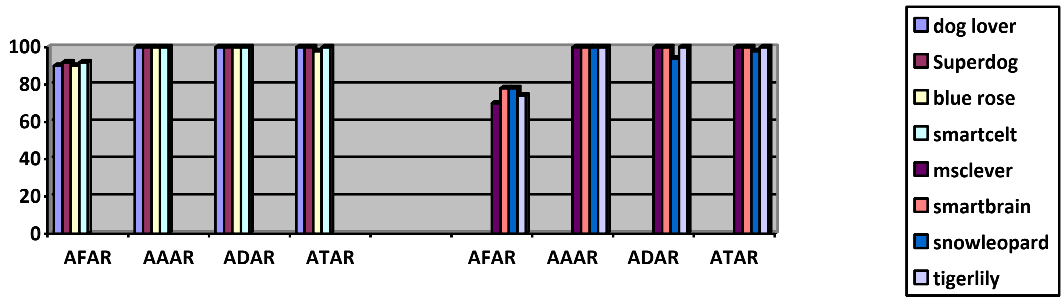

Figure 6.3: Histogram depicting the averages of assessment results in percentages. (Author)

[Note: AFAR --- Average Formative Assessment Results, AAAR --- Average Artefact Assessment Results, ADAR --- Average Device Assessment Results and ATAR --- Average Teacher Assessment Results]

As shown in the histogram in figure 6.3, AAAR (100% for each student) and ATAR of the low-ability students in heterogeneous and homogeneous groups are the same. This indicates that both groups had the same treatment from artefact and teacher. There are little variations in ADAR between both groups. These little variations in ADAR indicate that both groups had almost equal treatment from the device. There are high variations in AFAR between the low-ability students in the heterogeneous and homogeneous groups, and thus, the low-ability students in the heterogeneous groups in average were involved in greater formative assessments (group work attitude, interest for maths, reasoning etc.) than the low-ability students in the homogeneous group, and as a result, this had impacts on their post-test scores.

<u>Research Question 2</u>

Using the MLC, will there be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken ?

- Null hypothesis 2 - *Using the MLC, there will be no significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*
- Alternative hypothesis 2 - *Using the MLC, there will be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the homogeneous group for the topics taken.*

The result of the analysis for the total average post-test score is shown in table 6.9.

μ (HT)	μ (HM)	Δ μ	
91.1	55	36.1	
91.7	55.6	36.1	
87.8	57.2	30.6	
86.1	56.1	30	
356.7	223.9	132.8	Total
89.2	56	33.2	$\mu_{total\mu}$
		45.7%	Δ%

Table 6.9: Total average post-test score for the topics taken by the heterogeneous and homogeneous groups. (Author)

$\mu_{total\mu}$ is the mean of the total mean values. $\Delta\%$ is percentage difference between the total post-test score of the heterogeneous and homogeneous groups. Percentage difference is the difference between two values divided by the average of the two values expressed as a percentage.

As shown in table 6.9, the percentage difference between the heterogeneous and homogeneous groups' total average post-test scores is high, thus satisfying the alternative hypothesis of research question 2. The nature of this outcome depended on the total average formative, total average artefact, total average device and total average teacher assessment results. The averages of these assessment results are presented in the bar chart of figure 6.4. The first four plots represent those of the heterogeneous groups and the last four plots represent those of the homogeneous group.

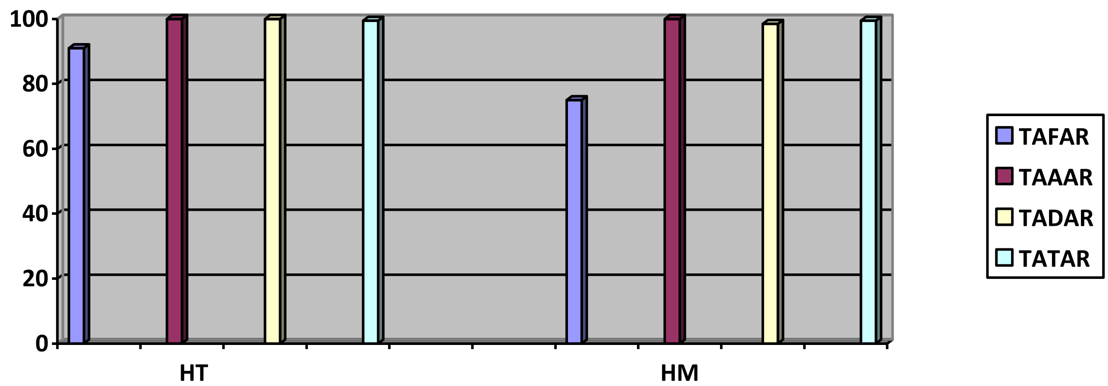

Figure 6.4: Bar chart depicting the average totals of assessment results in percentages. (Author)

[Note: TAFAR --- Total Average Formative Assessment Results, TAAAR --- Total Average Artefact Assessment Results, TADAR --- Total Average Device Assessment Results and TATAR --- Total Average Teacher Assessment Results]

As shown in the bar chart in figure 6.4, TAAAR of the low-ability students in heterogeneous and homogeneous groups are the same, indicating they had equal treatment from artefact. There are little variations in TADAR and TATAR between the low-ability students in both groups, indicating they had almost equal treatment from the device and teacher. There are high variations in TAFAR between the low-ability students in both groups, and thus, the low-ability students in the heterogeneous groups in average total were involved in greater formative assessments (group work attitude, interest for maths, etc.) than the low-ability students in the homogeneous group, and as a result, this impacted on their post-test scores.

<u>Research Question 3</u>

Using the MLC, will there be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the homogeneous group for the topics taken?

- Null hypothesis 3 - *Using the MCL, there will be no significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the homogeneous group for the topics taken.*
- Alternative Hypothesis 3 - *Using the MCL, there will be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the homogeneous group for the topics taken.*

Having stated research question 3, the results of post-test were analysed and resulted in the outcome in table 6.10.

Students	Post-Test Scores (%)								
dog lover	70	85	90	95	95	90	100	95	100
msclever	55	60	55	60	45	55	50	50	65
Δ in scores	**15**	**25**	**35**	**35**	**50**	**35**	**50**	**45**	**35**
Superdog 123	65	90	95	95	95	95	100	90	100
smartbrain	50	60	55	55	65	50	55	50	60
Δ in scores	**15**	**30**	**40**	**40**	**30**	**45**	**45**	**40**	**40**
blue rose	70	80	85	85	95	85	100	95	100
snowleopard	60	65	60	60	50	45	60	50	65
Δ in scores	**10**	**15**	**25**	**25**	**45**	**40**	**40**	**45**	**35**
smartcelt	65	75	80	90	90	85	100	95	95
tigerlily	50	50	55	45	60	55	65	55	70
Δ in scores	**15**	**25**	**25**	**45**	**30**	**30**	**35**	**40**	**25**

Table 6.10: post-test scores for students in heterogeneous group and corresponding students in homogeneous group. (Author)

As shown in table 6.10, the post-test results of each student in the heterogeneous group is tabulated against the post-test results of the corresponding (linked) student in the homogeneous group. The differences (Δ **in scores)** in the post-test scores between each student in the heterogeneous group and the corresponding student in the homogeneous group are huge for the topics taken. Thus, the results or outcome of this analysis in table 6.10 satisfies the alternative hypothesis of research question 3.

<u>Research Question 4</u>

Using the MLC, will there be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken?

- Null hypothesis 4 - *Using the MCL, there will be no significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken.*
- Alternative Hypothesis 4 - *Using the MCL, there will be significant differences in the average mathematics post-test scores of the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the average mathematics post-test scores of corresponding low-ability fourth class primary school students placed in the separated group for the topics taken.*

To address this research question, the post-test scores of the students in the heterogeneous and separated groups is analysed here. This leads to the following results in table 6.11.

Student groups	Student names	Post-Test Scores (%)									µ (%)
Heterogeneous group (HT)	dog lover	70	85	90	95	95	90	100	95	100	91.1
	Superdog 123	65	90	95	95	95	95	100	90	100	91.7
	blue rose	70	80	85	85	95	85	100	95	100	87.8
	smartcelt	65	75	80	90	90	85	100	95	95	86.1
Separated group (SP)	brainbuster	40	35	45	40	30	35	35	45	50	39.4
	galaxy	50	45	45	35	35	30	30	50	55	41.7
	mars 123	55	50	35	40	30	30	30	60	60	43.3
	redrose	55	45	40	30	40	35	35	55	45	42.2

Table 6.11: Post-test scores of the low-ability students in heterogeneous and separated

groups with the averages. (Author)

Further Analyses of the outcome in table 6.11 leads to the outcome in table 6.12.

Post-test scores' averages (%)								$\mu_{average}$	δ
91.1	91.7	87.8	86.1	39.4	41.7	43.3	42.2	65.4	23.8

Table 6.12: Differences between the means of the post-test scores of the students in the heterogeneous and separated groups. (Author)

[Note: $\mu_{average}$ is the mean of the averages of the post-test scores, and δ is the standard deviation of these averages]

The results of analysis in table 6.12 is presented in the bar chart in figure 6.5.

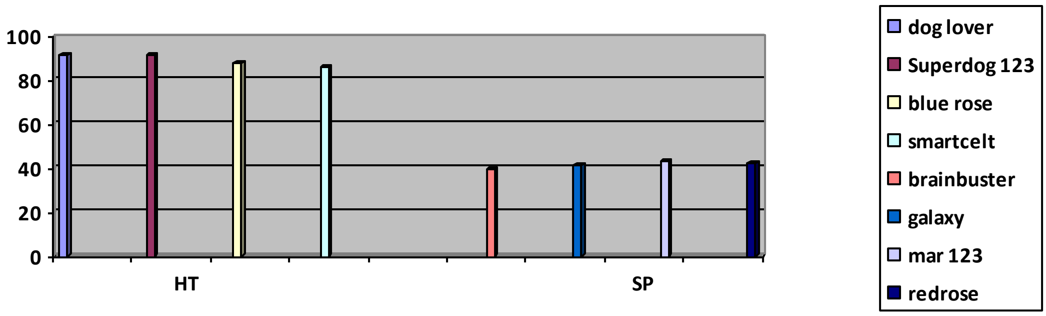

Figure 6.5: Bar chart depicting the variations (differences) between the means of the post-test scores of the students in the heterogeneous and separated groups. (Author)

[Note: The first four plots represent the average post-test scores of the students in the heterogeneous group and the last four plots represent those of the separated groups. The names of the students are shown on the right with colours of their plots]

As shown in the bar chart in figure 6.5, the average post-scores of the first two students in the heterogeneous groups are a little more than one standard deviation, 23.8, above the average mean ($\mu_{average}$) while those of the last two students in the heterogeneous groups are a little less than one standard deviation above $\mu_{average}$. The average post score the first student in the separated group is a little more than one standard deviation below $\mu_{average}$ while the average post scores of the last three students in the separated group are a little less than one standard deviation below $\mu_{average}$. Thus, the outcome of the analysis, presented on the bar chart in figure 6.5 satisfies the alternative hypothesis of research question 4.

The nature of this outcome depended on the average formative, average artefact, average device and average teacher assessment results. The averages of these assessment results are presented in table 6.13 and the plot is shown in the histogram of figure 6.6. The first four plot blocks represent those of the heterogeneous groups and the last four plot blocks represent those of the separated group.

The average formative assessment results (AFAR) for a student in the heterogeneous and separated groups are the average of the student formative assessment results by the teacher and self-formative assessment results. Also, note that the peer formative assessment results of the students in heterogeneous groups were excluded from this result analysis since the students in separated group were not involved in peer formative assessment. The average teacher assessment result (ATAR) is the average of the teacher assessment results by the student and teacher self-assessment results.

Group	Student names	AFAR	AAAR	ADAR	ATAR
Heterogeneous Group (HT)	dog lover	4.3	5	5	5
	Superdog 123	4.4	5	5	5
	blue rose	4.3	5	5	4.9
	smartcelt	4.6	5	5	5
Separated Group (SP)	brainbuster	2.6	4.9	4.7	4.6
	galaxy	2.6	5	4.9	4.9
	mar 123	2.5	4.7	4.9	4.9
	redrose	2.3	5	5	4.9

Table 6.13: Averages of assessment results in percentages. (Author)

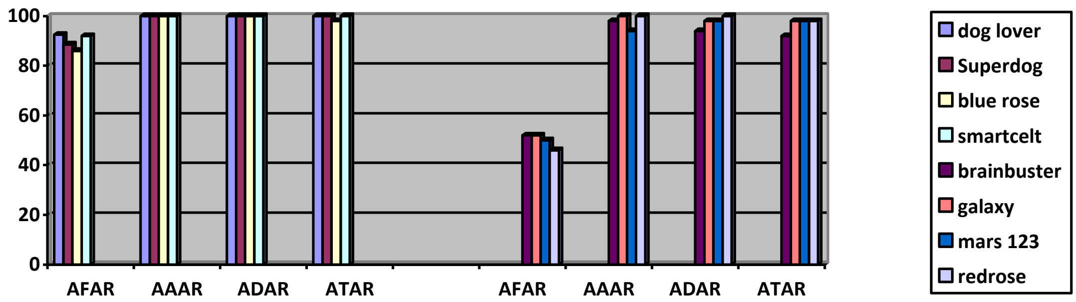

Figure 6.6: Histogram depicting the averages of assessment results in percentages. (Author)

[Note: AFAR --- Average Formative Assessment Results, AAAR --- Average Artefact Assessment Results, ADAR --- Average Device Assessment Results and ATAR --- Average Teacher Assessment Results]

As shown in the histogram in figure 6.6, there are little variations in AAAR, ADAR and ATAR between the low-ability students in the heterogeneous and separated groups. These little variations in AAAR, ADAR and ATAR indicate that both groups had almost equal treatment from the artefact, device and teacher. There are high variations in AFAR between the low-ability students in the heterogeneous and separated groups. Thus, the low-ability students in the heterogeneous groups in average were involved in greater formative assessments (interest for maths, self-confidence, reasoning etc.) than the low-ability students in the separated group, and as a result, this had impacts on their post-test scores.

<u>Research Question 5</u>

Using the MLC, will there be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken ?

- Null hypothesis 5 - *Using the MLC, there will be no significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken.*
- Alternative hypothesis 5 - *Using the MLC, there will be a significant difference in the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in heterogeneous groups with the high-ability fourth-class students compared to the total average mathematics post-test score of all the low-ability fourth-class primary school students placed in the separated group for the topics taken.*

To address this question, the post-test scores of the heterogeneous and separated groups were analysed, leading to the outcome in table 6.14.

μ (HT)	μ (HM)	Δ μ	
91.1	39.4	51.7	
91.7	41.7	50	
87.8	43.3	44.5	
86.1	42.2	43.9	
356.7	166.6	190.1	Total
89.2	41.7	47.5	μtotalμ
		72.6%	Δ%

Table 6.14: Total average post-test score for the topics taken by the heterogeneous and separated groups. (Author)

As shown in table 6.14, the percentage difference between the heterogeneous and separated groups' total average post-test scores is high, thus satisfying the alternative hypothesis of research question 5. The nature of this outcome depended on the total average formative, total average artefact, total average device and total average teacher assessment results. The averages of these assessment results are presented in the bar chart of figure 6.7. The first four plots represent those of the heterogeneous groups and the last four plots represent those of the separated group. Note that the peer formative assessment is excluded from this analysis.

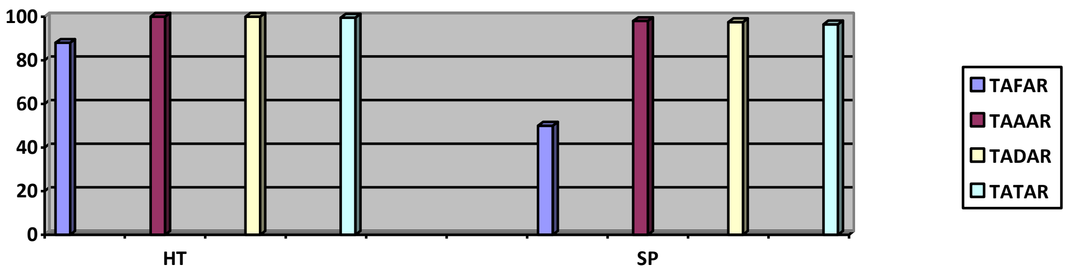

Figure 6.7: Bar chart depicting the average totals of assessment results in percentages. (Author)

[Note: TAFAR --- Total Average Formative Assessment Results, TAAAR --- Total Average Artefact Assessment Results, TADAR --- Total Average Device Assessment Results and TATAR --- Total Average Teacher Assessment Results]

As shown in the bar chart in figure 6.7, there are little variations in TAAAR, TADAR and TATAR between the low-ability students in heterogeneous and separated groups, indicating they had almost equal treatment from artefact, device and teacher. There are high variations in TAFAR between the low-ability students in both groups, thus, the low-ability students in the heterogeneous groups in average total were involved in greater formative assessments (interest for maths, reasoning etc.) than the low-ability students in the separated group, and as a result, this had impacts on their post-test scores.

<u>Research Question 6</u>

Using the MLC, will there be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth class primary school student placed in the separated group for the topics taken?

- Null hypothesis 6 - *Using the MCL, there will be no significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the separated group for the topics taken.*
- Alternative Hypothesis 6 - *Using the MCL, there will be significant differences in the mathematics post-test scores of each low-ability fourth-class primary school student placed in a heterogeneous group with the high-ability fourth-class students compared to the mathematics post-test scores of a corresponding low-ability fourth-class primary school student placed in the separated group for the topics taken.*

Having stated research question 6, the results of post-test were analysed and resulted in the outcome in table 6.15.

Student names	Post-Test Scores (%)								
dog lover	70	85	90	95	95	90	100	95	100
brainbuster	40	35	45	40	30	35	35	45	50
∆ in scores	**30**	**50**	**45**	**55**	**65**	**55**	**65**	**50**	**50**
Superdog 123	65	90	95	95	95	95	100	90	100
galaxy	50	45	45	35	35	30	30	50	55
∆ in scores	**15**	**45**	**50**	**60**	**60**	**65**	**70**	**40**	**45**
blue rose	70	80	85	85	95	85	100	95	100
mars 123	55	50	35	40	30	30	30	60	60
∆ in scores	**15**	**30**	**50**	**45**	**65**	**55**	**70**	**35**	**40**
smartcelt	65	75	80	90	90	85	100	95	95
redrose	55	50	35	40	30	30	30	60	60
∆ in scores	**10**	**25**	**45**	**50**	**60**	**55**	**70**	**35**	**45**

Table 6.15: Post-test scores for students in heterogeneous group and corresponding students in separated group. (Author)

As shown in table 6.15, the post-test results of each student in the heterogeneous group is tabulated against the post-test results of the corresponding (linked) student in the separated group. The differences (∆ **in scores)** in the post-test scores between each student in the heterogeneous group and the corresponding student in the separated group are huge for the topics taken. Thus, the results or outcome of this analysis in table 6.15 satisfies the alternative hypothesis of research question 6.

6.5.1 Key Findings

This research based on the outcome of the analysis of the empirical (experiment) results, suggests that low-ability math students learn more in heterogeneous groups than homogenous and separated groups, and in addition, even high-ability student show increased learning outcome in the heterogeneous groups.

It is widely believed that heterogeneous groups benefit lower-achieving students by giving them access to the intellectual resources of higher-achievers, and according to Webb et al. (1997), low-achieving students learn more in heterogeneous than in homogeneous groups. Burris et al. (2007) and Marzano et al. (2001) argue that that low-track students even learn more in heterogeneous groups. Webb et al. (1997) and Johnson and Johnson (1999) indicated that high-achieving students show equally strong learning outcomes in heterogeneous. Evidence of this were the research experiments conducted in Healy (2010) and Linchevski and Kutscher (1999) which suggested that heterogeneous grouping benefits more to low ability student than homogeneous grouping.

For further justification of the analysis, the average score gains (average difference between post-test and pre-test results) of the low-ability students in the heterogeneous groups for each of the topics were very enormous as shown in percentages in the bar chart of figure 6.8.

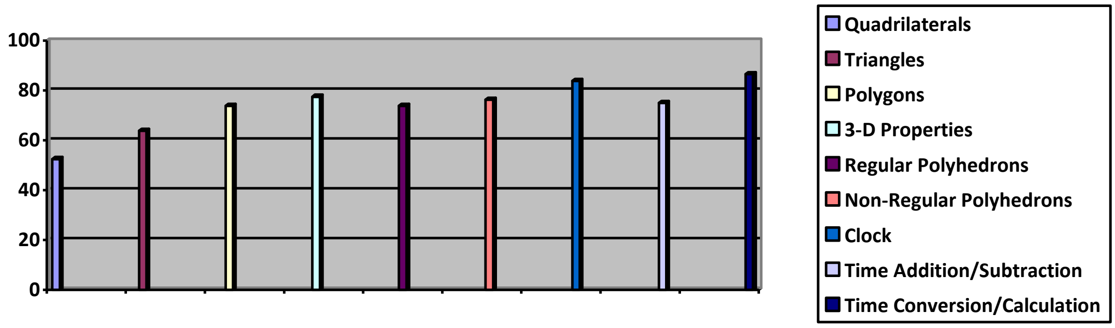

Figure 6.8: Average score gains of the low-ability students in the heterogeneous groups for each topic. (Author)

Those of the homogeneous group were high but much lower than those of the heterogeneous groups as shown in the bar chart in figure 6.9.

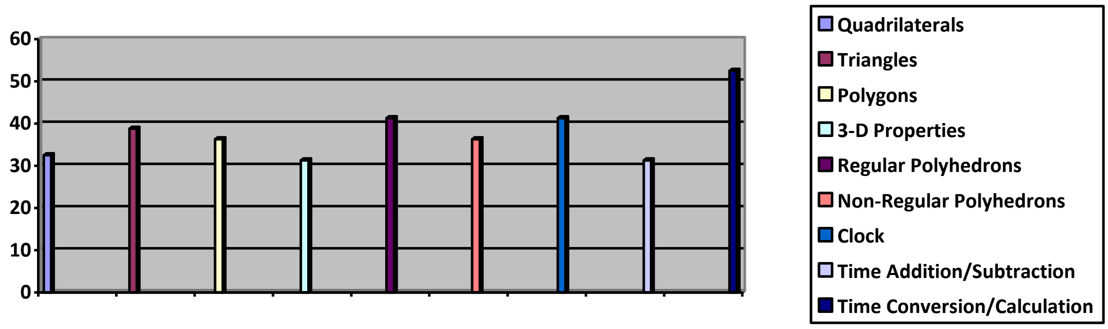

Figure 6.9: Average score gains of the low-ability students in the homogeneous group for each topic. (Author)

Those of the separated group were high but very much lower than those of the heterogeneous groups as shown in the bar chart in figure 6.10.

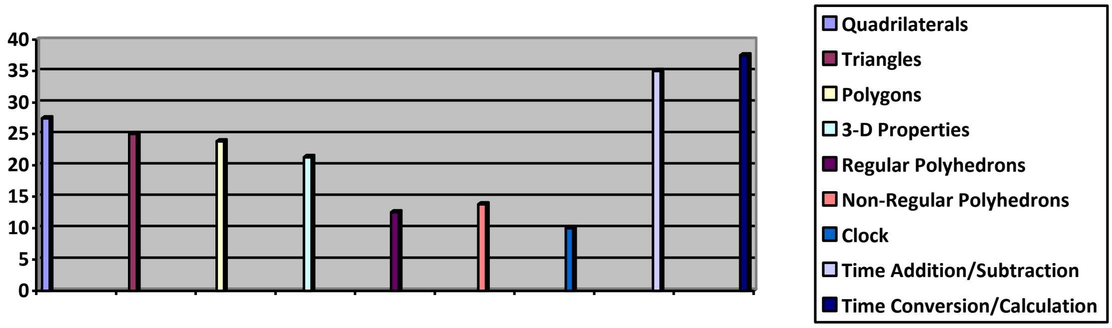

Figure 6.10: Average score gains of the low-ability students in the separated group for each topic. (Author)

As shown in the bar charts above, the low-ability students in the heterogeneous groups learnt more than those in the homogeneous and separated group. Despite this, these results equally suggest that the students in the homogeneous and separated groups learnt as well. The nature of the outcome above was dependent on the student involvement in the device and artefact usage, also on how the they related to each other in the group and how the teacher supported them. These independent variable results are shown below in figure 6.11. These results are the total average formative assessment results (TAFAR), total average artefact assessment results (TAAAR), total average device assessment results (TADAR) and total average teacher assessment results (TATAR).

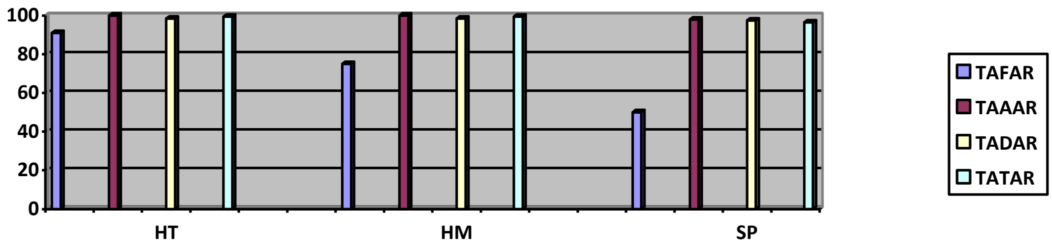

Figure 6.11: Bar chart depicting the average totals of independent assessment results in percentages. (Author)

TAFAR for the separated group did not involve group work attitude, coordination, interpersonal relationship and communication. As shown from the analysis results above, there were not much differences between the heterogeneous groups (HT), homogeneous group (HM) and separated group (SP) in the in terms of artefact, device and teacher facilitation. The huge difference lies in the involvement of students themselves. The results show that the low-ability students in the heterogeneous groups (HT), in average total, improved more in understanding and recalling, reasoning, idea Integration and connection, application and problem solving, implementing, interest for mathematics, achievement motivation, self-confidence, group work attitude etc. during the learning session than those in the homogeneous group. They also, in average total, improved more in these qualities (with the exception of the four mention above) than those in the separated group.

The fact is that some of the students in homogeneous groups commented that some of their group members do not work well with them. [Note: All the comments made by the students and teacher are included in the appendix K of this research document]

What this shows is that a new or additional means has to be devised to increase the students' involvement in learning so that they can get more out of it. In addition, the teacher should be frequently asking the students some questions during the formative assessments in learning, but not wait for the students to call his or her attention, which means that the application no matter how easy it is cannot completely replace the teacher's responsibilities. In addition, contextual variables related to the composition of a group with respect to any sociological, psychological and preferential variables should be considered in order to see how they affect the student performance.

6.6 Conclusions

This chapter looked into the experiment performed in this research in order to support some hypotheses. The experiment preparation took six days in which the students were given some pre-lessons and pre-tests to distinguish between the high and low achievers in mathematics. The experiment execution took nine days in which the students were separated into four groups with high and low-mathematics achievers, and then given post-lessons, and post-test afterwards. The results from the pre-tests and post-tests were analysed to verify whether the low-ability students learnt from the high-ability students.

This research has looked into some areas of knowledge to elicit information for support. This information is the foundation upon which this research is based. Although this research has been successful in eliciting information and addressing those questions facing it, it nevertheless cannot be complete without some future work recommendations, which amongst several others, will be discussed in the next and final chapter of this research.

7. Conclusions and Future Work

7.1 Introduction

After careful analysis of the empirical evidence (experimental results) in this research, the results of the analysis suggest that heterogeneous groups benefit lower-ability students in mathematics achievements by giving them access to the intellectual resources of higher-achievers.

With this in mind, this chapter conclusively summarises this research by looking at the problem definition and overview of the research, contributions it has made to the body of knowledge, experiment, evaluation and limitations involved in the research and future work and research in areas of this research.

7.2 Problem Definition and Research Overview

The primary area of research for this project was on heterogeneous grouping, computer supported collaborative learning and effect that this heterogeneous grouping has on the mathematics achievement of the low-ability primary school students in the computer collaborative learning environment.

The secondary research was divided into six parts:

- The first part was to examine education philosophy and e-learning focusing on the nature of computer-aided learning and heterogeneous grouping.
- The second part was to investigate the current views and research conducted on heterogeneous grouping on computer supported collaborative learning environment.
- The third part was to develop an experiment to determine how this mode of grouping affects the mathematics achievement of the low-ability primary school students in a computer supported collaborative learning environment. [Note: Questionnaires and interviews were rendered at this stage]
- The fourth part was to document and evaluate the findings from the experiment. [Note: Questionnaires, interviews and test feedbacks were retrieved at this stage]
- The fifth part was to suggest whether primary schools that have computing devices will

employ this mode of grouping more in their mathematics lessons based on the evaluation results.

- The final part was to make recommendations for any future research in this area.

7.3 Contributions to the Body of Knowledge

This research made the following contributions to the body of knowledge:

- The E-learning database (MLCDB) developed for this research was developed after a thorough research on e-learning systems and consideration on what information should be included in the database and after eliciting requirements from the users and careful analysis of those requirements. This database schema (MLCDB) created in this research is the first that has been developed for facilitating computer supported collaborative learning, and should facilitate future e-learning database design.
- The application, Math Learning Collaborator (MLC), was developed after a thorough research on many areas on e-learning systems and considerations on the GUI designs and implementations, and after eliciting requirements from the users and careful analysis of those requirements. This application (MLC) developed in this research is the first that has been developed for facilitating computer supported collaborative learning, and should facilitate future e-learning application design.
- Suggestion of using heterogeneous groupings to teach and learn mathematics in primary schools that have computing devices with the likes of these applications installed. This will aid the low-ability students to learn more, and even the high-ability students will benefit from it.
- The study as a whole can be referenced in any future research.

7.4 Experimentation, Evaluation and Limitations

- This research only focused on sixteen primary school students from Presentation Primary School.
- Pre-lesson and pre-test materials were administered to the students under nine topics before applying the treatment to observe how the treatment, when applied, will affect the students' achievement by comparing the pre-test results to the post-test results that resulted from that treatment.

- The sixteen students were divided into four groups based on their pre-test results, and each group was made up of four students.
- The first two groups were the heterogeneous groups consisting of two high and two low-ability Math students. These heterogeneous groups were the experimental or treatment group and the last two groups were the homogeneous and separated groups consisting of four low-ability Math students each. These last two groups were the control groups.
- Post-lessons and post-tests were administered to these groups under nine topics, and equal treatments were given to all groups e.g. teacher's monitoring, equity, teacher's communication, guidance etc., and the results of the post-tests were analysed, some of which include comparison with the pre-tests results.
- This research did not consider contextual variables related to the composition of a group with respect to any sociological, psychological and preferential variables e.g. team member gender, personal preferences, and level of team member familiarity or age.
- This research did not include video-interviews of primary school participants in order not to violate data protection rights of the participants, and especially the child safety rights of the students.

7.5 Future Work and Research

These are some areas of this research that need recommendation for future work and research. These include:

- Expanding the dataset by including more students since larger dataset would result in a higher degree of accuracy.
- Considering the impacts of students' learning styles and the instructors' teaching style.
- Considering contextual variables related to the composition of a group with respect to any sociological, psychological and preferential variables e.g. team member gender, personal preferences, and level of team member familiarity or age, and then determining whether their presence may have positive or negative influence on the student performance.
- Employing a flipped classroom scenario and exploring how effective the MLC system is in that context.
- Looking at the range of students that can be classified as either high-ability or low ability, or exploring if different students in those ranges benefit more from the group work or the eLearning environment.

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8 Appendices

8.1 Appendix A: Letter of Authority of Access to Primary School

Presentation Primary School
Warrenmount

To Whom It May Concern

June 28th 2013

This letter certifies that James Ndukwe conducted research for his dissertation in our school Presentation Primary Warrenmount during the month of June 2013 over a three week period beginning June 10th and ending June 28th 2013. If you have any questions please don't hesitate to contact the school.

Yours sincerely,

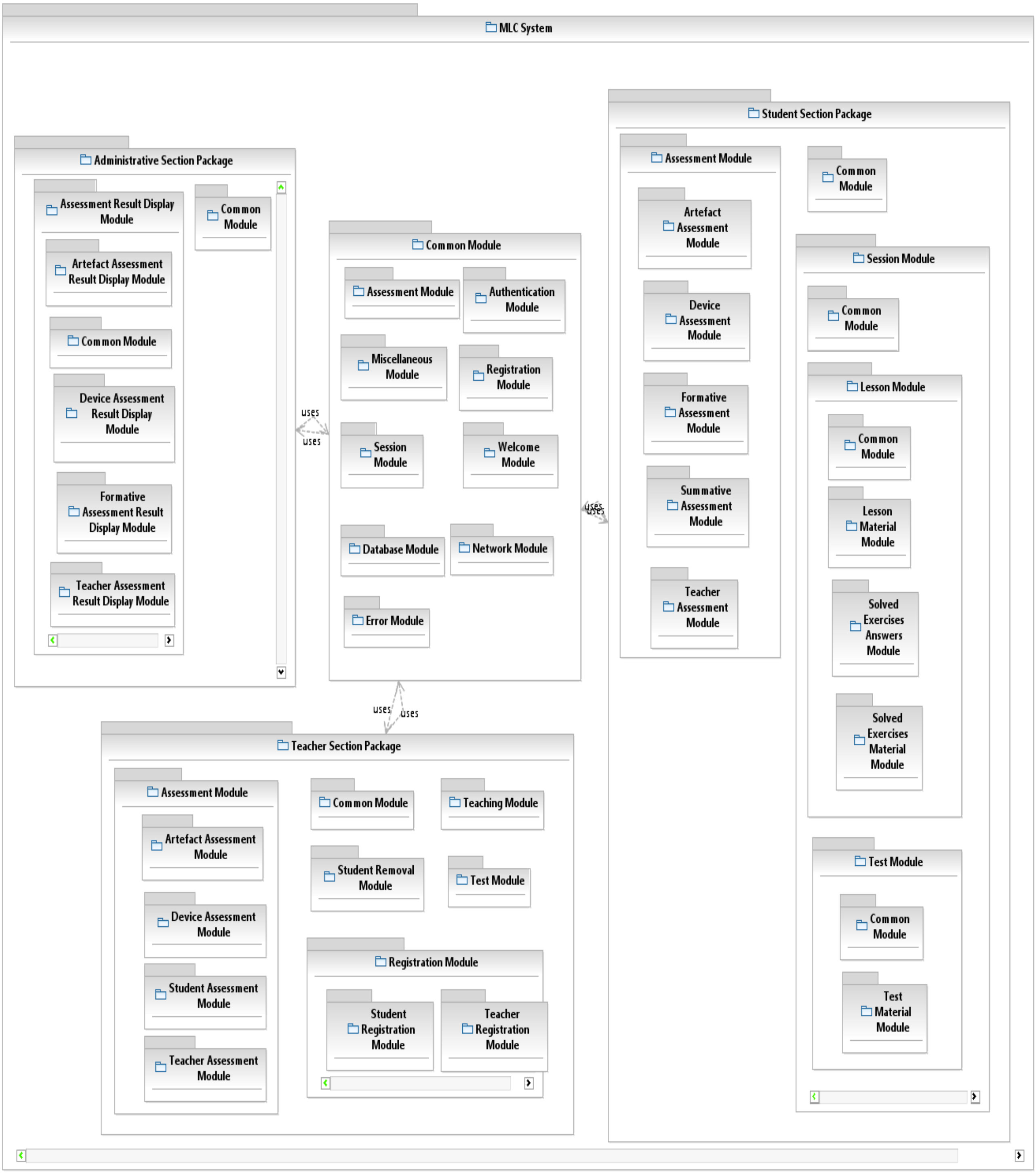
Presentation Primary School
Warrenmount
Blackpitts
Dublin 8
Ph. 01 4539547
www.warrenmountprimary.com

Maria Diskin Class Teacher ICT Coordinator

Maria Diskin

Presentation Primary School, Warrenmount, Blackpitts, Dublin 8.
Phone: (01)4539547 Fax: (01)4530203 E-mail: warrenmt@eircom.net
Website: www.warrenmountprimary.com

8.2 *Appendix B: MLC System Module Structure. Diagram created using Rational Software Architect Standard Edition, V7.5.0 [Author]*



8.3 Appendix C: Requirement Analysis

See accompanying CD.

8.4 Appendix D: Design

See accompanying CD.

8.5 Appendix E: Testing

See accompanying CD.

8.6 Appendix F: Results from Experiment

See accompanying CD.

8.7 Appendix G: Screen Capture of All Summative Assessment Results

See accompanying CD.

8.8 Appendix H: Application Implementation

See accompanying CD.

8.9 Appendix I: Sample Pre-Lesson and Pre-Test Materials

See accompanying CD.

8.10 Appendix J: Sample Post-Lesson and Post-Test Materials

See accompanying CD.

8.11 Appendix K: Responses to Rating Questionnaires

See accompanying CD.

8.12 Appendix L: Follow up Interviews (Audio)

See accompanying CD.

8.13 Appendix M: Pictures and videos taken during the experiment

See accompanying CD.