Teacher Educators’ Professional Development towards Educational Research in Student-Centered Instruction Supported by Dynamic Mathematics Software

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Abstract

This research study was an explorative qualitative study. The participants were two teacher educators from Kotebe College of Teacher Education in Ethiopia.

The study addressed the expressed needs of teacher educators by designing a professional development scenario. In this scenario the teacher educators had autonomy to construct their own knowledge, suggest their own ideas, and they had ample opportunity to explore and discover on their own. The scenario was designed to encourage the participants to learn by doing, work in a collaborative team, and develop a feeling of ownership for what they contributed to a discussion. Their learning was supported by dynamic mathematics software, samples of practical study materials, videos and photographs. It helped them to be engaged, to be critically reflective and work independently.

In the joint educational research phase in the professional development scenario the teacher educator developed their own student activities using dynamic mathematics software, practiced student-centered instruction in their own classes and also developed their own research instruments. They acquired knowledge of how active learning instruction can be realized in practice. The aim of this research was to investigate the effect of the scenario and the collaborative teamwork on the teacher educators’ professional development.

The research results indicated that the professional development scenario enabled the teacher educators to develop research ability. The outcomes have enabled me to suggest a new professional development model which, if followed, is likely to lead to sustainable professional development.
To my lovely daughters Semernaise and newborn Mister; and my wife Gelanie

for their love
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## Contents

Abstract .................................................................................................................................................. iii

Acknowledgements .................................................................................................................................... Vii

List of Figures .......................................................................................................................................... Xi

List of Tables ........................................................................................................................................... Xii

1 Introduction ........................................................................................................................................ 1

2 Theoretical Framework ......................................................................................................................... 3
   2.1 Professional Development and Crucial Factors for Teachers Change ........................................... 3
   2.2 A Different Approach to Research ............................................................................................... 4
   2.3 A Way Forward in Professional Development .............................................................................. 6
   2.4 Collaborative Training for Teachers’ Professional Development ................................................. 7
   2.5 Using Artifacts for Professional Development ............................................................................ 8
   2.6 Capacity Building and Sustainability of Teacher Change ............................................................ 10
   2.7 Summary Literature Reading on Professional Development ..................................................... 11

3 Research Questions and the Educational Research Settings .............................................................. 13
   3.1 Research Questions ....................................................................................................................... 13
   3.2 The Educational System of Ethiopia ............................................................................................ 15
   3.3 Research Setting ............................................................................................................................ 17
   3.4 The Diploma Program in Mathematics at KCTE ........................................................................... 18
   3.5 Background of My Research Co-Workers .................................................................................... 18

4 Research Design and Methodology ...................................................................................................... 21
   4.1 Research Design and Planning ...................................................................................................... 21
      4.1.1 My Summer Visit to Ethiopia, August 2011 .......................................................................... 21
      4.1.2 The Use of GeoGebra in the Professional Development Scenario ........................................ 22
      4.1.3 Expectations in My Research ............................................................................................... 22
      4.1.4 Time Line for the Research .................................................................................................. 23
      4.1.5 Training Material Used in Professional Development Scenario ......................................... 23
      4.1.6 Researcher’s Planning and His Strategy ............................................................................... 25
      4.1.7 Phases of the Professional Development Scenario ............................................................. 25
   4.2 Research Methodology .................................................................................................................. 26
      4.2.1 The Teacher Educators Role During the Professional Development Scenario .................... 26
Appendices

A. Time Line for the Research .......................................................... 105
B. Training Material used in Professional Development Scenario ............... 107
C. Final Interview Questions for Teacher Educators ................................ 113
D. Student Activity Sheets Designed by Gizachew ................................ 115
E. Student Activity Sheets Designed by Sebsibe ................................. 121
F. Post Lesson Interview Transcriptions ............................................. 125

List of Figures

Figure 3.1 The Educational Structure of Ethiopia ..................................... 16
Figure 3.2 The Educational Structure of KCTE ....................................... 17
Figure 6.1 A Picture taken from video of Tessema’s Wintor Project (2011) ........ 52
Figure 6.2 A Photo of a GeoGebra Classroom in Napal (Mainali’s, 2008) ........ 57
Figure 6.3 Gizachew’s Applet for asking students background knowledge about definition of sine, cosine and tangent functions ........................................ 61
Figure 6.4 Gizachew’s Applet I: For angle \( \theta = 30^\circ, 60^\circ, 90^\circ, ..., 360^\circ \) ........ 62
Figure 6.5 Gizachew’s Applet II: For any angle \( \theta = 0^\circ, 1^\circ, 2^\circ, ..., 360^\circ \) ........ 62
Figure 6.6 Gizachew’s Applet III: For any angle \( \theta \geq 360^\circ \) ..................... 63
Figure 6.7 Sebsibe’s first trial applet on exponential functions .................... 64
Figure 6.8 Gizachew’s pilot study: Students working with the activities and Gizachew observing ........................................................... 67
Figure 6.9 Sebsibe’s pilot study: Students working in a group and their teacher giving some instruction ..................................................... 68
Figure 6.10 Shows minor change in Gizachew activity sheet after the pilot study .. 69
Figure 6.11 Group of students in Gizachew class ..................................... 76
Figure 6.12 Gizachew’s class with other groups ...................................... 77
Figure 6.13 Sebsibe helping one group ................................................ 77
Figure 6.14 Sebsibe’s class ................................................................. 78
Figure 6.15 A student group worksheet in Gizachew’s lesson .................... 80
Figure 6.16 A student group worksheet in Sebsibe’s lesson. Here students were able to develop their own rule .................................................. 81
Figure 7.1 A model for Sustainable Professional Development in Research .... 97
List of Tables
Table 6.1 Colleagues students’ Questionnaire………………………………………... 74
Table 6.2 Colleagues’ interview questions for both groups……………………….. 74
Table 6.3 Overview of observers…………………………………………………………... 75
R: Your daughter tried ...oh ...

S: No no ... I tried for her. I tried when she disturbed me ...when I work ... to make her busy I constructed this applet for her ...hahahaha

R: Really ... Ok show me ... this is surprising ... what she said

**Applet constructed by Sebsibe for his daughter**

S: I made it simply to make her busy ...she played with it

G: I also tried at home ... the Thales Theorem ... it is really nice

**Applet constructed by Gizachew**

R: Ok ... you guys ... it shows me really you are motivated

G: After I constructed the applets ... I think it is nice to show to the students easily the Thales Theorem ... that is to show the angle sum of the triangle in a semicircle is 180° ... it is really surprising me

S: I see it is nice... you make also animation ...oh it is really nice

G: I hope students will like it ...and they will understand easily.
Chapter 1 Introduction

In the Ethiopian educational system for a long time, the way of teaching has been mostly dominated by teacher-centered instruction. In this instructional setting the center or the control of the teaching and learning processes is mostly teacher dominant. Nowadays, in educational policy documents and educational research documents there is a shift of thinking about different ways of teaching that focus on students as the center of the teaching and learning processes (Ayele, Schippers, & Ramos, 2007).

The Ministry of Education in Ethiopia (MoE) is currently implementing a new program that promotes the practicality of student-centered learning methods in all levels of education in the country. Since 2003, the government of Ethiopia has officially opted for an apparently ambitious reform in the structure and content of teacher education. The main aim of the MoE for teacher training institutes that is the curriculum should be geared to the training for pre-service and in-service teachers in the new reform (MoE, 2010).

Nowadays employment of learner-centered, active-learning, and problem solving pedagogical approaches and terms such as quality, accessibility, relevance, cognitive ability, competence, school experience, and practicum have been frequently mentioned in various policy documents (Ayele, Schippers, & Ramos, 2007). Ethiopian education researchers mainly concentrate on policy and curriculum problems. There seems to be no educational research results that guide the introduction of a student-centered approach to mathematics teaching with the support of a digital environment.

The teacher training institutes were informed about new methods like active learning, constructivism and inquiry learning, but educators have never seen real examples. For instance, in Kotebe College of Teacher Education (KCTE), the College where I implemented my research, my colleagues and many of the teacher educators did not have clear ideas of how to introduce student-centered instruction. Because of this some of the instructors in the Mathematics Department of KCTE thought they were not training future teachers in any kind of student-centered method in a practical way. This was true not only for KCTE, but for all teachers training institutes in the country.
Personal Motivation

Before I came to Amsterdam to study in the MMSE program\(^1\) I did not have much idea about how a digital environment could be used to support the teaching of mathematics in a student-centered manner. Through the study program I got experience on how to use information and communication technology (ICT) for creating lesson activities in a student-centered learning approach and how to research the effects of these activities. Also one project in the program, the Winter Project, gave me experience in educational research in a real classroom situation at a secondary school in Amsterdam. My experience in doing this project was an eye opener for me in doing research in mathematics education. I began to see also how a digital environment could improve mathematics education by helping teachers to visualize and create connections between mathematics ideas and concepts. It can also be used to represent mathematics concepts in different forms and also make it easy for the students to visualize the concepts.

It was during my study that I got the practical and theoretical knowledge to do research in ICT-supported education. After this first experience, I had the idea that a similar project could be beneficial for Ethiopian mathematics educators. I talked about it with my colleagues at KCTE, and they liked this idea and were willing to do such project. They were interested to do educational research geared towards a student-centered way of teaching in their own courses. They were eager to see in practice how such an approach could work and to design activities to implement in their own classrooms, and research the effects.

To this end, I designed a professional development scenario which was implemented with two colleagues at the Mathematics Department. The purpose of my research was to find out at how this professionalization worked in practice. This research encompassed two studies, the longer is my master study about the professional development of two teacher educators who as part of their professionalization designed and carried out a small first research project with their own students. Thus, describing one research project within another has required that extra pointers be given readers than is normally done in a master thesis. Therefore, some description of the professional development scenario process is in Chapter 4 in order to set the stage and clarify what actually happened before getting into the fuller description in the data analysis and findings (Chapter 6).

\(^1\)MMSE Master in Mathematics and Science Education, University of Amsterdam
Chapter 2 Theoretical Framework

In this chapter I explore some research results from the literature, including how teacher change occurs by participating in professional development programs, the effect of teacher educators own practices and collaboration work on their professional development, the use of artifacts, and the capacity building and sustainability teacher change in the professional development process. Finally, I summarize the main findings in the literature.

2.1 Professional Development and Crucial Factors for Teacher Change.

In many countries professional development of teachers is one of the core aims for the development of education. Professional development refers to training practicing teachers rather than preparing students to become first-time teachers. Many have strived to develop an efficient method to foster the development of the skills and knowledge of new teachers. Regarding instructional practice in the past two or more decades, in most educational institutions researchers have acknowledged and indicated the importance of teachers’ practice in their own classroom. Professional training and educational institutes have been funded in many countries with the aims to produce qualified practitioners to foster and increase their country’s educational development. For this, many institutions aimed to train and encourage teachers to conduct research in their classrooms to enhance and develop their own practice (Postholm, 2008).

Research results show that most professional development programs are unsuccessful in meeting their main objective, and indeed Guskey (2002) argues that professional development programs in most cases fail to address their main goals. There are a variety of factors related to this lack of success. Guskey (1986) suggested successful professional development should address two critical issues: “what motivates teachers to engage in professional development”, and knowing “the process by which change in teachers typically occurs”. According to Guskey (2002) the main reasons that teachers are motivated by professional development is that they hope and believe that by taking part they will obtain new knowledge and additional skills, it will contribute to their career development, and afterwards they will be able to enhance student learning. In addition to this, many teachers hope to gain practical, specific, and concrete experience through professional training (Guskey, 1986). The other factors that must be considered for professional development of teachers, according to Guskey (2002), are the process of teacher change and the difficulties encountered in helping them to change their practice.
Guskey (2002) further argued that teacher change only after seeing results from their students which appear to be due to their practices in the classroom. “They believe it works because they have seen it work, and that experience shapes their attitudes and beliefs” (Guskey, 1986). In this Guskey shared Crandall’s ideas on how teacher change occurred: “Teachers tried the new practice, mastered it, saw results with their students, and developed a strong sense of ownership” (Crandall, 1983). This also coincides with my view that teachers’ new practices and experiences with their own students are both vital if they are to grow in a professional sense.

2.2 A Different Approach to Research

According to Postholm (2008) teacher professional competency will increase if teachers conduct some research into their own practice. This will help them to reflect on their work and actually to study and learn about what they do. Postholm (2008) also indicated that reflection processes help teachers to develop their teaching by enabling them to think in new ways and to see things from other angles. This means that teachers should be encouraged to develop research skills which could facilitate some change.

From another point of view Greeno (1998, p. 21) argued that “research could include efforts to understand the tacit assumptions of practices and to collaborate with practitioners who want to change their practices in directions that can be supported by a better understanding of assumptions of both their present and their desired practices.” As a proponent of an interactive research perspective in professional development, Greeno (1998) suggested: “Conducting interactive research and design requires a different kind of collaboration with practitioners than researchers have had traditionally.” To implement this kind of research requires a recognition of the main difference between traditional and interactive research: “In traditional relationships, researchers mainly have been outside observers and analysts, whereas teachers have been subjects of the research, or research has been conducted away from the domain of practice and researchers have formulated their recommendations as prescriptions that teachers should follow” (Greeno, 1998, p. 22).

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2Interactive research could be defined as a situation in which teachers and researcher work together within certain conditions.
This means that in traditional research teachers have been merely a channel for the transfer of researcher knowledge and practices to their own students. It seems that in this view teachers become a means through which the researcher learning is addressed to the rest of the society in one or another form. On the other hand in interactive research and design “teachers are the principal designers of change in their practices and, to a significant extent, are coinvestigators in the research that has their practice as its main topic” (Greeno, 1998). This implies that teachers become change agents of their classroom practice by being directly involved in the researching of their own teaching. To the latter end, Greeno (1998) argued that the traditional separation of activities among research, developing materials, and strengthening practices is not the only way to support the advancement of science and educational practice. Instead, he proposed collaborative work among the researcher, teachers and all the community, which in his view would make the research results durable and innovative. “In spite of the relative separation of these communities of accountability, there can be close collaboration among researchers, developers, and practitioners in the design of material resources, the evaluation and improvement of these resources and their uses, and the production of information for research” (Greeno, 1998, p. 22). It means that the teachers’ active participation and a focus on their practices are critical for their professional development. It appears from this literature that in many cases teachers would change their practices, as well as their beliefs and attitudes, if they could see that their actions promote change in students’ learning.

Postholm (2008) also argued that when teachers develop their research skills they will become better teachers. To bring changes in teachers’ practice, researchers and teachers should work in a collaborative manner (Postholm, 2011, p. 7): “The researcher should adopt an active role together with the participants in the research to attempt to change the practices. Changing a practice may thus be initiated and occur in relation to the common notions held by both the researcher and practitioners when it comes to how a changed practice should be”. Postholm suggested that by working collaboratively and by allowing teachers to contribute their own ideas to the professional development, a change in their practice would be inevitable. In sum, if professional development and research practices include and give opportunity for teachers to practice and to contribute their own views and ideas during discussion, it will indeed affect their practice.
2.3 A Way Forward in Professional Development

Guskey (1986) argued that in successful staff development process researchers or trainers must offer to teachers practical ideas that they can successfully use in their own classrooms. This means that teachers could develop knowledge and skills by offering them different teaching practices that are concrete and suited to their day-to-day needs. According to Putnam & Borko (2000), “One particular effective approach to situating learning occurred when members of the staff development or research team introduced materials and activities in a workshop session, the teachers attempted to enact these ideas in their classroom.” This means that teachers can learn from others’ ideas if they perceive them to be good practice.

A case study based on video recordings could facilitate teachers’ learning when they can observe, albeit at a distance, how others incorporate geometry software, for example, with their students. Putnam & Borko (2000) argued that such case-based learning provides a workable approach for creating meaningful settings for teacher professional development with the support of video as evidence. In addition, “because the unique power of video to convey the complexity and atmosphere of human interactions, video case studies provide powerful opportunity for deep reflection” (Nemirovsky & Galvis, 2003). It seems that, case-based learning should help teachers to interact with specific situations which connect with their day-to-day practices. In this way teachers might more easily recognize the connections to the real situations of their daily experience.

Postholm (2011) suggested that when teachers directly participate and take part in research they will be motivated to try something by themselves. “Teachers see how the researcher collects data, analyzes, interprets and draws conclusions that emerge in conversations they have. In this way teachers may also learn some strategies for how research may be conducted and thus have the opportunity to use these strategies in future development activities” (Postholm, 2011). So if teachers see how a new strategy works and also if they have developed a habit of trying something new on their own, then eventually they will start to develop new practices in their classrooms. Janssen, Westbroek, Doyle, & Van Driel (in press, 2012) argued that “practicality theory posits that the judgments teachers make about the utility of change proposals determine the likelihood they will be adopted”, an idea also shared by Doyle (2011).
2.4 Collaborative Training for Teachers’ Professional Development

According to Prusak, Hershkowitz, & Schwarz (2011) the word *collaborative* is defined as “a situation in which two or more people learn or attempt to learn something together.” Here I use the term *collaborative training* which has a similar meaning to *collaborative learning*. In this research study the term *collaborative training* refers to the collaborative work between experienced teacher educators and a researcher, all of whom work in an educational training institution. In much educational literature we find *collaborative learning* in a context with student learning, and most of the time the results are focused on primary and/or secondary level student learning. It is rare to find research results which show teachers engaging in *collaborative learning* or *collaborative training* with a researcher. I have chosen to use *collaborative training* because the context here is teacher not student learning.

In the collaborative training in the research reported in this master thesis an environment was established that enabled teacher educators to become responsible for one another’s learning, as well as for their own individual learning. The shared environment of the training setup gave the teachers an opportunity to contribute and discuss critically to probe the underlying meaning of what they were doing during the training period. According to Putnam & Borko (2000) “a number of educational reformers have argued that for teachers to be successful in constructing new roles they need opportunities to participate”. This means that teachers’ direct participation and construction of new knowledge is crucial for their professional development. Putnam further argued that “when diverse groups of teachers with different types of knowledge and expertise come together in discourse communities, community members can draw upon and incorporate each other's expertise to create rich conversations and new insights into teaching and learning” (Putnam & Borko, 2000). This point could be extended to mean that when experienced teachers are involved in collaborative training, they can discuss critically and suggest their own ideas in meaningful ways. They take responsibility and are accountable for the construction of the new knowledge. According to Greeno (1998, p. 22) “Each member of the group takes on some of the responsibility for all of the aspects of the work, and, indeed, several members of the team work as both a teacher and a developer, as both a developer and a researcher, or as both a teacher and a researcher.” This means that in collaborative training each participant can act as contributor and learner at the same time. In other words, it means that there is no autonomous person or group for the construction of the new knowledge among the participants; all are equally important. In
support of this idea Postholm (2011) argued that new knowledge and skills are created in the close collaboration processes between participants and researcher.

There are two aspects for developing knowledge and skills of participants through collaborative training (Duckworth, 1986, p. 481); “The first is to put students into contact with phenomena related to the area to be studied, the real thing, not books or lecturing about it and help them notice what is interesting; to engage them so they will continue to think and wonder about it”. This means encouraging the participants to use their previous knowledge to try and come up with solutions by themselves with support of real phenomena. It is also important “to have the [teachers] try to explain the sense they are making, and, instead of explaining things … to try to understand their sense” (Duckworth, 1986, p. 481). This can be accomplished by letting participants conjecture and discuss on their own, based on their own thinking. For adults, collaborative training must have a well-designed environment that encourages participants to construct their own knowledge. Collaborative training will also encourage teacher educators to coach each other, and it will give them an opportunity to contribute their own ideas. So in this way, the training should promote professional development.

2.5 Using Artifacts for Professional Development

In education, artifacts are cognitive tools which are used to represent ideas or concepts. The word artifact has many meanings and interpretations in different fields of study. An artifact can be example words or an ICT tool (Postholm, 2011). In many cases the aims of using artifacts for teachers has been to support students’ learning. I use the word cognitive tool to mean a psychological tool as an aid to learning, but this term is extended to ICT within which Dynamic Geometry software is denoted as a cognitive tool. Another interpretation is that artifacts or cognitive tools might give more clarification to students’ learning. Jonassen and Reeves (2000, p. 695) have argued that “cognitive tools could enable students to learn, to organize, restructure, and represent what they know”. This means that in many ways cognitive tools may have a profound effect on the representations of ideas or concepts.

In recent years cognitive tools like those in ICTs have shown a great impact in educational development. “The current developments across the world have moved much beyond the vision of using ICT as a teaching and learning aid, but of reshaping the delivery of instruction and bringing about changes in education” (Wong, Li, Choi, & Lee, 2008). Wong, et al. also argued
that ICT technology innovations bring about change in practices in the teaching and learning process. Now a day has arrived when having ICT-supported lessons using student-centered instruction seems promising. “ICT has made a positive impact on changing the modes of teaching and learning in classroom practices from a teacher-centered approach to one that is student-centered” (Wong, et al., 2008).

Despite its promise for the development of education, most of the time the integration of ICT in school practice seems impractical. “Teachers ineffective use of technology has been reported in the literature, and the focus of research is shifting to designing appropriate activities and providing effective pedagogical strategies for the teaching and learning of mathematics in a models and modeling perspective” (Haciomeroglu, Bu, & Haciomeroglu, 2010). This implies that there should be professional development for teachers which should show them how to design and practice effectively the use of ICT in their own classroom. Haciomeroglu, Bu, and Haciomeroglu also suggested that having knowledge of ICT does not imply that teachers change their practice or use it effectively as a cognitive tool in their own classrooms. “Since knowing how to use technology does not ensure knowing how to teach with it, simply introducing technology or modeling teaching with technology might not be sufficient to change their conception about teaching and learning mathematics” (Haciomeroglu, Bu, & Haciomeroglu, 2010). In my opinion, in many countries teachers use ICT as tools to support their traditional teaching. In many cases teachers in both universities and schools use a presentation software tool or word processing software to present their lectures by projecting it while giving their talk. They use a presentation software tool as a simple replacement of the blackboard. This means that they simply augment their delivery of the lecture.³

³This information has been informally gathered from colleagues and from my own observation of teacher practice in Ethiopia.
In support of this point, Putnam and Borko (2000, p. 10) argued that, “the most widely adopted tools are those that fit easily within the existing conceptual and social organization of [classroom] drill-and-practice programs that can be used by individual students without interfering with whole-class activity, word-processing tools for preparing instructional materials, presentation tools that can replace overhead projectors, and tools for keeping attendance and grades.

Such tools can support teachers in doing what they already do, but have little potential for transforming the work of teachers or the nature of teaching and learning in classrooms.” It appears that to bring about change in the effective use of ICT in education, there must be effective professional development training as well as research into the different possible uses of ICT. This should include addressing the issue of how to use it practically in order to bring successful change. As Putnam and Borko (2000, p. 10) put it: “additional research is needed to determine how such guidance should be designed and made available, to maximize its potential for fostering educationally worthwhile conversations among teachers.”

Currently in mathematics education, cognitive tools like GeoGebra promise the possibility of using ICT as an externalizing tool of our ideas more than as a substitution. This means that any ICT tool like GeoGebra helps teachers, students, and educators to explore, create, and investigate mathematics concepts. According to Karadag and McDougall (2011, p. 170) “teachers can use cognitive tools, particularly GeoGebra, in their instructional activities to explain, explore, and model mathematical concepts and the connections between these concepts”. The use of ICT like GeoGebra not only brings about change in education, it can also promote change in the teaching process to move towards a student-centered kind of instruction. In general it seems that cognitive tools like GeoGebra might bring and promote change from what teachers are doing now to a real shift from their present teacher-centered practice.

2.6 Capacity Building and Sustainability of Teacher Change

Professional development in many cases is initiated and proposed by educational institute agencies for the aim of improving student learning. Newmann, King, and Younks (2000) indicated that professional development for teachers is considered as a means of school improvement. In most cases professional development programs fail to succeed in their main
Newmann, et al (2000) argued that for professional development program to promote success, it must concentrate on student outcomes and provide opportunities for collegial inquiry. They proposed a “kind of teacher learning, combining help and feedback to connect teachers to external expertise while also respecting their discretion and creativity” (p. 259). This means that the incorporation of teachers’ ideas and needs is vital for the success of their professional development. Not only this, consideration of student learning could be one aspect of a good development program.

Murray, Campbell, and Hextall et al (2009, p. 945) maintain that one should “build capacity in the field of teacher education in three ways: firstly, by strengthening expertise, knowledge and understanding; secondly, by enhancing the individual and communal motivation of some of its researchers, and thirdly, by offering increased opportunities for collaborative work between universities and research communities”.

**2.7 Summary of Literature Reading on Professional Development**

The literature read and discussed in this chapter supports and extends my ideas about how collaborative training and participation in joint research might affect my colleagues’ professional development.

It seems clear from the literature that if teachers take active part in a research process through incorporation of their ideas and experience, they will take ownership of the research results. In this regard teachers will no longer be an avenue for the transfer of research learning, they will become a means for change in their own right. This could mean that the interactive or collaborative way of researching teacher practice could help teachers to develop their own profession.
Chapter 3 Research Questions and the Educational Research Setting

In this chapter I formulate the research questions and I describe the educational system in Ethiopia and the research settings including the background of the research co-workers.

3.1 Research Questions

The main purpose of this research study was to explore the extent in which a specially designed professional development scenario and the collaborative or joint educational research work helped two teacher educators to develop educational research ability. To investigate this development I formulated two main research questions.

Research Question 1

*To what extent did the professional development scenario contribute to the teacher educators’ learning of how to do educational research in their own classroom on student-centered instruction that is supported by dynamic mathematics software?*

First I would like to define what I mean by the terms *professional development scenario, student-centered instruction, and dynamic mathematics software* in the context of this research study. The term *professional development scenario* refers here to a particular environment that enabled participants to learn by doing. I initially set the scene for the professional development sessions, but thereafter the teacher-educators took ownership and came up with their own ideas for lesson activities with the intention of trying them out in their classrooms and exploring whether the activities met their expectations, i.e. by doing classroom research. I also gave the participants ample opportunity to explore, suggest, and create teaching ideas; to share experiences; and to reflect on their work. Resources for the professional development scenario were sample student worksheets, videos and photographs of students working in real classrooms, and dynamic mathematics applets developed by others.

*Student-centered instruction* puts students at the center of the teaching process; they become active in constructing their own knowledge. Group work and the use of computers are often applied to stimulate active participation. *Dynamic mathematics software* is software that enables teachers and students to represent their mathematics ideas in a dynamic way where mouse-
dragging is used to change objects on the screen. This has pedagogical implications. In this research I used GeoGebra.

I operationalized the main research question into three sub-questions.

1.1 Did observation and discussion of videos of classroom activities from others help the teacher educators to develop critical abilities regarding their own teaching?

1.2 Did the professional development scenario encourage the teacher educators to reflect on their own practice?

1.3 Did the incorporation of dynamic mathematics software facilitate the teacher educators to develop and practice student-centered instruction?

Research Question 2

To what extent did the teacher educators develop research ability by participating in joint educational research?

The main aspect of this research question is to find out how the teacher educators developed research ability by taking part in joint educational research. The term Joint Educational Research refers to the collaboration among the participants, the two teacher educators and the researcher. The involved persons formed a study group for developing research ability and doing research. Main activities were evaluating external materials (downloaded from the Internet, for example), developing instructional materials, discussing them as a team, making improvements on the basis of the criticism and suggestions, and designing research instruments to find evidence of the effectiveness of the designed materials in classroom practice (including preparation of observation sheets, questionnaires, and interview questions).

I operationalized again into three sub-questions.

2.1 Did the teacher educators learn to engage in critical reflection during the study group activities?

2.2 How did the study group activities enable teacher educators to develop research ability?

2.3 What impressions of doing classroom research were revealed in the interviews with the teacher educators?
In sub-research questions 1.1-1.3 I wanted to explore at how the professional development scenario, the use of ICT for practicing student-centered instruction affected the teacher educators professional development. For this the professional development scenario setup was designed to be a unique future of this research study. In sub-questions 2.1-2.3 I aimed to investigate how joint educational research can help teacher educators to develop some ability to research. The joint educational research with teacher educators was a second unique aspect of this research study.

3.2 The Educational System of Ethiopia

The Ethiopian Federal Democratic Republic is located in the so-called Horn of Africa. In Ethiopia formal education was introduced around 1800, but it took until after the Second World War for education to be given any amount of priority. Many educational institutions with a focus on teacher training were subsequently established. However, the majority of the population still had no access to education.

The current Ethiopian government recognizes the importance of education for national development. Educational policy is mainly aiming at expansion of the education sector, quality improvement, and harmonization educational content with the country's economic needs. In accordance with the federal structure, each of the country’s nine states and two urban administrations has their own educational bureaus (National Regional State Education Bureaus). These Bureaus are responsible for the administration and management of general education, technical and vocational education, and the teacher-training programs and institutions. The federal Ministry of Education is responsible for higher education. The Ministry of Education formulates policy and guidelines, which are implemented by the various Bureaus.

The education system comprises both formal and non-formal education. Non-formal education includes a broad scope of educational programs for all age categories, catering to both school leavers and new pupils. Formal education comprises pre-school education, primary and secondary education (general education), technical-professional education and higher education.

Higher education is currently high on the list of national priorities. The 2003 Higher Education Proclamation aimed to ensure that the higher education system contributes directly to the national strategy for economic development and poverty reduction. In 2009, a new Higher
Education Proclamation came into force, putting emphasis on, among others, higher education autonomy, quality and relevance of education and research, and on income generation.
Currently the number of primary and secondary schools is growing rapidly, and there are twenty-two public universities, twelve colleges, over forty private higher education institutions, and around ten teacher training colleges (adapted from Nuffic country report, 2012). A general overview of the education system in Ethiopia is given in Figure 3.1

**Figure 3.1 The Educational structure of Ethiopia**
3.3 Research Setting

In this research, the participants were two teacher educators from Kotebe College of Teacher Education (KCTE) in Addis Ababa, Ethiopia. KCTE was established in 1966 serving as a teacher training institute; it currently trains teachers for the pre-primary, primary, junior and secondary schools. The College runs two programs: a degree program and a diploma program. The degree program has only one field of study which is health and physical education with a duration of four years. The diploma program is a three year program which includes Languages (English and Amharic), Mathematics, Physics, Chemistry, Biology and Social Science (History, Geography, and Civics and Ethical Education). The College has good facilities such as a well-functioning computer center, a library, and a sports hall for its students and staff.

The Department of Mathematics is one of the oldest departments in the institute: it trains mathematics teachers for primary, junior, and secondary schools. I did my joint educational research with two teacher educators in the Mathematics Department. Both teacher educators have worked as mathematics instructors for more than fifteen years in this training institute.

The department has its own computer rooms and classrooms for training students for a diploma program. In the following section I briefly sketch and outline the educational structure of the College in Figure 3.2 and the program run by Department of Mathematics.

Figure 3.2 The Educational structure of KCTE
3.4 The Diploma Program in Mathematics at KCTE

The Diploma program has two different components based on the division of the primary education namely: first cycle (Grades 1-4) and second cycle (Grades 5-8). As per the direction given by the Ministry of Education, teachers for the first cycle of primary schools are trained in cluster form but those for the second cycle are trained in linear form. Courses have been designed for the cluster program with four options in natural science and mathematics cluster.4 The following mathematics courses designed for the linear program are: Basic Mathematics I & II, Plane Geometry, Introduction to Calculus, Solid Geometry, Fundamental Concepts of Algebra, Elementary Linear Algebra, Calculus I & II and Introduction to Statistics and Probability. The joint educational research project described in this master thesis involved the participation of students who were enrolled in the linear training program. The participants in this joint educational research are teaching one of the above mathematics courses for linear program students.

3.5 Background of the Research Co-Workers

In this section I outline the educational background of my colleagues. First I summarize Gizachew’s background and then Sebsibe’s and suggest how they progressed in the use of dynamic mathematics software.

Gizachew

Gizachew has been a teacher of mathematics for more than fifteen years at the KCTE. He obtained a master degree in mathematics education from a German University about fifteen years ago. In addition to this, he later graduated from Addis Ababa University with a master degree in information and computer science. Gizachew has knowledge and skills in both Information Technology and Computer Science. He sometimes teaches his mathematics courses using software like Mathematica, MatLab, Cabri II and various application software. He has used such software for presenting mathematics during his lessons and for calculating problems but not for teaching in a student-centered way. Though GeoGebra was new to him, it was clear early in the training that his previous experience helped him to catch on quickly to GeoGebra. He could easily figure out by himself some of the tools in the GeoGebra software.

4Course catalog of KCTE, 2009
Sebsibe

Sebsibe has been working as a teacher of mathematics for more than fifteen years at the KCTE. Sebsibe has a master degree in mathematics from Addis Ababa University. He has knowledge and skills in Information Technology and Computer Science. Like Gizachew, he sometimes teaches mathematics courses using mathematics software like Mathematica, MatLab, Cabri II, and various application software. He also uses such software in his class for calculations, or for presentations in his lessons, but not to teach in a student-centered way. When I introduced GeoGebra, he was a novice user of the software. His long experience in teaching mathematics plus some practical knowledge and skills from using various others mathematics software helped him to understand easily some of the tools of the dynamic mathematical software GeoGebra. Moreover his motivation and enthusiasm to know about the software helped him to figure out easily some of the tools in the software.
Chapter 4 Research Design and Methodology

In this chapter I discuss the research design and its planning, that is, how I designed the strategy and how I planned to establish a professional scenario. Finally I discuss the methodology that I used for data collection and data analysis.

4.1 Research Design and Planning

In this section I describe how the research ideas started and how I planned to do my research by developing material and designing a research strategy.

4.1.1 My Summer Visit to Ethiopia, August 2011

During my summer holidays in Ethiopia in 2011 I met my colleagues who asked me about my study program in Amsterdam. I explained the study program and its features. I told them that I was getting practical knowledge in mathematics and science education, like how to design a student-centered instructional approach using ICT tools like GeoGebra, how to do mathematics education research, and how to design student activities. They were very impressed and eager to know more about it during our discussion time. They told me that they also wanted to do such things but did not know how to do it or how to get started. They are experiencing a pressure from the government to practice this style of teaching and learning. For this reason in the College they had recently formed a Mathematics and Science Educational Research team. The research team focused on mathematics and science education research that would be relevant for the College. But there had been no progress in the direction either of actively doing their own research or of designing their own student-centered activities. From the discussion I understood that both my colleagues felt the same gap between theory and practice as I did and that they did not have a clear idea about how to progress. They wanted to get involved in learning how to design student-centered instruction and in researching its effects on their own students. This meeting was a pivotal moment for me in formulating my ideas for my research: the two colleagues Gizachew and Sebsibe would work with me as joint researchers in the framework of my master research project. They were enthusiastic, cooperative and willing to share their thoughts and practices in such a project, i.e., to become my colleagues who would be involved in joint educational research. In my own master research I was therefore able to focus on the development of my colleagues’ research ability during our joint work.
4.1.2 The Use of GeoGebra in the Professional Development Scenario

GeoGebra is dynamic mathematics software which combines algebraic and geometric features. In GeoGebra different representations of the same mathematics object are connected dynamically, allowing users to go back and forth between them, thereby making relationships among those representations more easily comprehensible for students. Whenever one of the representations is modified, all others adapt automatically in order to maintain the relations between the different objects on the screen. New objects can be created either by using dynamic geometric tools or algebraic keyboard input. By its provision for keyboard input, a range of predefined commands can be used in GeoGebra; mathematics topics other than geometry can be treated as well (Hohenwarter, Hohenwarter, & Lavicza, 2009).

I used GeoGebra as a cognitive tool in my research because it is designed for teaching and learning mathematics in secondary school, college and even in university level. From my experience in my Winter Project (Tessema, 2011) I found that the software combines the ease of use of dynamic geometry software with certain features of a computer algebra system and, therefore, allows for bridging the gap between the mathematics disciplines of geometry, algebra, and calculus. It also could be used to visualize mathematics concepts as well as to create instructional material. I used GeoGebra for my research project because it has the potential to foster active and student-centered learning by allowing for mathematical experiments, interactive explorations, as well as discovery learning. Not only this, it is freely available for any user is also an important aspect for my research project with my colleagues in Ethiopia.

4.1.3 Expectations in My Research

In my research, I expected that the involved teacher educators would learn by designing their own ICT-supported activities that endorse student-centered methods of teaching. They would design the activities using dynamic mathematics software to support their teaching. They would research the effects of changes in their own teaching and through these efforts they would have develop some research ability. I thought that they might be motivated to do this type of educational research in the future.
4.1.4 Time Line for the Research

The research study took a total of 11 weeks. The first three weeks were used to introduce GeoGebra. The introduction was done by demonstrating first, then creating an environment in which the teacher educators could work collaboratively. Next to this the teacher educators studied other researchers’ materials and practices through watching videos. This took almost two weeks. Hereafter the teacher educators engaged in developing their own instructional materials this also took two weeks. The teacher educators’ piloted their own research material and then developed their research instruments (another two weeks). Finally the implementation of their activities with their own students and collecting their own data also took two weeks for a total of 11 weeks in all (Appendix A).

4.1.5 Training Material Used in Professional Development Scenario

The developed training materials in this research consisted of three parts: (1) suggested topics for training, (2) lesson study materials from other researchers as case-studies and (3) sample research materials which illustrate how GeoGebra can be used to develop lesson material.

The suggested topics were taken from the linear course of KCTE (Section 3.4). The topics were selected to include algebra, geometry and calculus courses. There were eight suggested topics but in addition it was planned so that teacher educators would be free to add and suggest their own topics. Together the suggested topics included each of the subject area of mathematics (appendix B, part I). In appendix B, the first three topics 1, 2 and 3 focused on the geometry aspect. These topics were meant to help teacher educators to interact directly with the software but doing that in a way similar to working with in paper and pencil. The next four questions, that is topics 4, 5, 6, and 7 focused on both aspects of geometry and algebra. These questions were intended to help the teacher educators to interact with the software by manipulating the tool and the input command. The last question i.e. topics 8, was selected from calculus to help them to interact with other feature of the software like color, animation, text and so on. In addition to the eight suggested topics the teacher educators suggested their own topics like proofing Thales Theorem, Fibonacci Sequence, Rational Function and others.

5AMSTEL  Amsterdam Mathematics Science and Technology Education Laboratory
Two Winter Project in the MMSE program were used in my research. Three *lesson study materials* were selected. Two were from MMSE Winter Project, in Dutch schools (Tessema, 2011, and Wakwinji, 2010), while the third was part of MMSE master research project in Nepal (Mainali, 2008). The main reason for selecting these three projects was that they focused both on the student-centered way of instruction and both used GeoGebra to construct applets as part of the instructional materials. Moreover the three lessons take into consideration students’ background. The questions included simple to more challenging ones and were also designed to lead students to construct their own knowledge.

The reason for using Tessema’s Winter Project first was that the classroom arrangements of this lesson were somewhat similar to the KCTE computer lab setup (Section 3.3). I thought that this would help the teacher educators to associate the lesson environment more easily with their own situation. Wakwinji’s lesson as the second showed a more advanced classroom arrangement and a different style of student-centered group formation. It was decided to put Mainali’s last because his lesson environment was quite similar to an Ethiopian school situation.

Videos of Tessema’s and Wakwinji’s lesson studies were shown. Only photographs of Mainali lessons were available. Tessema’s video showed students working in groups with one desktop computer for each group so this helped my colleagues to relate it to their own computer lab situation. Wakwinji’s lesson study involved a classroom setup in which students worked individually with their laptop computer but at the same time with their group. As before, the two lesson studies were intended to help my colleagues to understand different group formations in student-centered instruction. In Mainali’s photographs the classroom setup was a typical example of a classroom type in Ethiopia with a large class size, but showing students working in a student-centered instruction way. Mainali used one laptop and a beamer in his class projecting GeoGebra on a white hung on one of the classroom walls.

*Sample research materials* were used to show how GeoGebra could be used to develop lesson materials and how to do a small research project in mathematics education. I also gave my colleagues an article downloaded from the GeoGebra web site.6

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4.1.6 Researcher’s Planning and His Strategy

I developed materials that addressed needs expressed by the teacher educators during my meeting with them in August, 2011 (section 4.1.1). They wanted to see how student-centered instruction could work in practice, and also example of teaching materials developed to support the new practice, how mathematics software could be used to support teaching, and finally how a small research study could be tried in their own classroom.

For this research project I planned to work collaboratively with the teacher educators. During the professional development scenario my activity was to conduct the training by demonstration, having frequent interviews with my colleagues plus a final interview, ask for frequent reflections (written, informal discussion, discussion of sample training material), show and discuss the videos and photographs and GeoGebra supported instructional materials, and to lead them to conduct a pilot study of their own developed materials.

My main strategy during the professional development scenario was to establish a collegial working environment, insure there was shared ownership, strive for development of collaborative teamwork, build trust among team members, promote authority sharing, encourage autonomous work habits, and help colleagues to establish exploratory habits with the software.

4.1.7 Phases of the Professional Development Scenario

The professional development scenario had four phases: Training, development, implementation and data analysis. Each phase had its own aim and goal. In the training phase teacher educators were expected to work collaboratively with the researcher. In the development phase teacher educators developed their own lesson study material. In the implantation phase teacher educators implemented their new way of teaching with selected group of student. Finally they analyzed the data from their own research.
4.2 Research Methodology

This qualitative research study was an exploratory case study. Two teacher educators with little or no experience in educational research were involved in the joint education research team with me as the third team member. Tasks were designing student activities, reflecting on their own practices, suggesting ideas, and discussing how to design the activities. Together, we designed student activities that link with a learner-centered method of teaching with the support of dynamic software.

The data were collected through semi-structured interviews with both participant teacher educators and their students, from reflection notes of the researcher and collaborative teachers, from recordings of all discussions with the teacher educators over the 11 weeks research period, from the designed prototypes of activities, classroom observation, and from video and audio recording of the teacher educators’ classes in which they implemented their designed lessons.

The teacher educators’ research had two phases (1) a pilot study phase and (2) an actual research phase. In the pilot study they used a group of first year mathematics students (randomly selected) to test the developed activities before implementing them in regular class and revised their lessons. Their actual research phase was implemented after they had seen results from the pilot study. The pilot study helped teacher educators to make ready the developed activities and the research instrument to research their own practice.

4.2.1 The Teacher Educators Role during Professional Development Scenario

The role of the collaborative teacher educators in the training period can be described in terms of active participation during discussions; making suggestions for their own lesson topics and taking ownership of the GeoGebra training. During the training time my colleagues were active contributors of their own ideas and concepts for the construction of applets and the design of activities. They and the researcher worked collaboratively during the whole training period except the first day. Their role changed throughout from that of listeners and observers to real participants. Their previous knowledge and skills of mathematics, ICT technologically and pedagogical, and teaching experience helped them to understand easily the features of the software. Their knowledge and skills changed in quality from novice user of the GeoGebra software to competent user.
At the point of making their own applets, they were clearly able to control the software and use it to enable them to address their main professional aims. Their long term friendship and professional relationship in the college and their work experience in different positions contributed much to their teamwork with respect to each other. Thus they were able to contribute and discuss easily as close and valued colleagues in the professional development scenario.

4.2.2 The Researcher Role during the Professional Development Scenario

My role as researcher at first was demonstrator of the GeoGebra software but this role began changing almost at once and continued to do so through the training period. Listing in order these role were demonstrator, then guide, next mentor, finally equal participant and contributor in the construction of applets and the design of instructional activities. I was able to establish a professional development environment that was conducive for teacher educators to try their own things, think freely, and suggest their own ideas and to be creative. According to Postholm (2011) research that aims to control the research process as little as possible during the research period has been carried out within the positivist and interpretative paradigm.

In addition to this, I provided learning and working environment within which we three were able to achieve close collaboration. “The researcher must aim to create new ways of carrying out actions together with the local participants” (Postholm, 2011). This means that the researcher should adopt an active role together with the participants in the research to attempt to change the practice. “Changing a practice may thus be initiated and occur in relation to the common notions held by both the researcher and participants when it comes to how a changed practice should be” (Postholm, 2011).

This gave them ownership and great responsibility during the training period to contribute their own knowledge and skills independently. In reflecting on all of this I can say that actually I worked as catalyzer of their discussion to mesh their previous knowledge and skills with their new knowledge, skills, and goals.
4.2.3 Data Collection Methods

To answer the main research and sub-research questions, I used:

- Frequent semi-structure interviews at the end of each session,
- A final interview at the end of my research after 11 weeks,
- Reflection notes,
- Colleagues design sheets (Appendix D and E),
- Video and audio recordings of the brainstorm sessions, and
- Intermediate results (GeoGebra files)

Semi-Structured Interviews

I interviewed teacher educators to answer the main research questions and sub-research questions. The interviews were recorded in audio.

Frequent short interview was done during the research process. There was one interview in the training phase, three interviews in the development phase and one interview after the implementation phase. In the training phase the purpose of the interview was to see how much the training helped teacher educators to develop skills and knowledge of how to use GeoGebra to construct applets, to know their perceptions and impressions about the educational use of GeoGebra software, and to investigate their developed reflection skills on their own practice.

In the development phase there were three interviews after observing and critiquing lessons of other people. The interview questions were meant to explore the teacher educators’ perception and impressions of others practice. I also wanted to know whether they had developed a mental conception of how student-centered instruction could be practically implemented in a classroom.

In the final interview there were thirteen questions (Appendix C). The first six questions focused on asking about their reflecting skills, impression of the software, perceptions about designing student-centered instructional activities using GeoGebra. The seventh Interview question focused on the effect of collaborative work on their professional development. The last six interview focused on whether and how the professional development scenario played a part in the development of their research skills.
Data from Video, Audio Recordings and Design sheets

In order to answer the main research question and sub-research questions I observed the teacher educators’ classes and recorded the lessons using both video and audio. I also recorded sessions with the teacher educators during lesson design and I kept the original design sheets (flow of the design).

Reflection Notes

The teacher educators were reflected by writing about their own practice and skill development. The reflection notes were one of the sources of data to answer my main research question. Their note gave me important information about each meeting about the teacher educators’ inspirations and their perceptions of being participants in this joint research work.
Chapter 5 Analysis Framework

The analysis method that I used is described here; it is based on the collected data from discussions, interviews with the teacher educators, student worksheets, the interview with students, student questionnaires, GeoGebra files and reflection notes of the teacher educators during the professional development scenario.

5.1 Pivotal Moments

Data from discussions were collected using audio recorder and then the data of each sessions of the professional development scenario were transcribed. Finally the data were analyzed based on the pivotal moments of the discussion. The pivotal moments are indicators of some kind of change in the teacher educators.

Examples

- Clearly altered a previous perception
- Understood what student-centered instruction is, practically speaking
- Understood how dynamic mathematics software can support instruction
- Indicated in some way their confidence using new skills and/or knowledge
- Changed their role from follower to leader or to a collaborative role
- Took autonomous action

A pivotal moment is identified, for example, by a clear utterance of a participant or an expression of an obvious change in perception.

Interviews

Data from interviews were collected throughout the professional development scenario (Appendix F). All interviews were transcribed in their entirety. Each answer of the interview questions was interpreted and analyzed. Some answers to the interview questions were directly quoted.
5.2 The Practical Work of the Professional Development

A close qualitative analysis was done of all resources in the professionalization trajectory.

*Reflection Notes of teacher educators*

Data from the *reflection notes* were collected during the training phase only. During much of the 11 week period of my research, the teacher educators had many college-related duties in addition to participating in the professional development scenario in their spare time. Hence, they had to reduce the frequency of written reflections. In spite of this I was able to use their reflections not only from their reflection notes but also from our discussions while working together. The data from their reflection notes are directly quoted when teacher educators critically reflect on their own practice and learning.

*Student Interview, Worksheet and Questionnaires*

The data from the *student interview, student worksheets and questionnaires* were used to support the result that the professional development scenario had brought change to the teacher educators’ professional development. As a reminder there was only one interview with students. Randomly selected data from the students’ interview, worksheets and questionnaires were transcribed. The responses which contribute to answering the questions were grouped first according to the question. The analysis was then structured in the following ways: the transcriptions of the response from the interview as well as the questionnaires were grouped, similarities or different answers were identified and analyzed.

*Research Instrument Designs, Applet Constructions and Lesson Material Design*

The data from *research instrument design, applet construction and lesson material design* were transcribed and analyzed.

*Short Summary of session*

The data from each session were summarized using short notes. These notes contained the highlights of the main findings of the sessions. The analysis was based on those points that indicated skill development, knowledge acquired, and when there was a change in thinking by the teacher educators.
Chapter 6 Data Analysis and Findings

In this chapter I summarize my colleagues’ conceptions of mathematics education research and their use of ICT for teaching mathematics, in particular the use of GeoGebra in mathematics education. This is all relevant for my research because I planned to base my work on my colleagues’ active and direct participation plus their contribution to the discussions during the training period and on their educational background knowledge and skills.

Firstly I outline my colleagues’ active and direct participation plus their contribution to the discussions during the training period, and then their mental conception development about student-centered instruction. Finally I report their developed skills and knowledge of activity design using GeoGebra and the analysis of the results after implementing their lessons. The results are organized to phase.

6.1 Training Phase

The training phase lasted four days with 3-4 hours training each day. In this section I outline each day’s activities and finish with a summary.

6.1.1 First Day of Training

The main objective of the first day of training was that my colleagues would get acquainted with using GeoGebra applets and the construction of them. I demonstrated the use and construction of GeoGebra applets by examples taken from the list of course topics that my colleagues had sent me beforehand. During the demonstration, I was sitting behind my laptop in the middle touching the keyboard and using the mousepad, with my colleagues sitting next to me. In the demonstration session I did not discuss each and every feature of the software, as if I was going thoroughly through a manual. Instead, I wanted to illustrate to my colleagues that the GeoGebra software can be used as a toolkit to do mathematics. For this purpose I did a geometric constructions with line segments, circles and perpendicular lines in the classical mathematical way of using ruler and compass methods. During my construction I explained a little bit about the tool bar and the menu items that I used. The following transcript may give an impression of how this demonstration went and to what discussions it led.

R: For today let’s start first by constructing line segment
S&G: Hmm...ok

R: You know that line segment is made of between two points ... here [pointing at tool bar item] you can find the point here... and select any point [clicking on location in the graph window] ....and connect using line segment tool ...here here that is [pointing at tool bar item]

G&S: Hmm...hmm...

R: When I construct the line segment above I used [a geometry tool ]...here [pointing at input bar]; also in the input bar you can use command [entering the first characters of the word “segment” in the input line]...you see here [a pop-up window appeared]...it is the same to draw segment using Geometric or Algebraic methods, that is, using tool menu or input command

G&S: Hmm....I see...hmm...

R: Let me show you also for the circle ...you can use this tool menu [pointing at tool bar] ...here...ya it is here you can select one of the two options. The first one is a circle with center point and you can draw it here for any radius as you like, as you want ...like this and for the second one ...let me select it... ya ...you should give the value of the radius here ...ok

G&S: Hmm...ok

At this stage of the demonstration Gizachew had a question about the educational use of the software:

G: But I do have a question...my question is if you are going to apply and use this software in elementary school for instance ...

R: Ok ask me ...ya ask me

G: My question is... if you are going to apply this software to elementary school students. I mean what [is] its advantage because I suggest from my point of view students should learn by doing themselves ...I mean you can have points and then they try to join the points ... it may not be straight-line when they are connecting by themselves and finally
they may have some idea about the line segment …but here you draw it and what is the practice for the students …where is the task for the students?

The fact that Gizachew was asking this question about the use of GeoGebra in school practice indicates that he had no difficulty in following the demonstration of the use of the software in doing mathematics. It triggered him simultaneously to start thinking about teaching this in his classroom. But I wanted to postpone the discussion about didactics and responded accordingly:

*R: This is a training for you … now I simply introduce you to how the software works. I hope finally you will see it*

*G&S: Hmm…ok*

In essence, my reply to the question was a simple reminder that we were in this session just focusing on the use of the software, not on didactical aspects. I was only showing how the software environment could be used as a mathematical toolkit. They agreed, and I continued the demonstration in this style by showing the construction of a perpendicular line using basic geometrical principles.

*R: Let me show you the construction of perpendicular line*

*G&S: Ok ok …*

*R: Let us give a line …here we can have a line …and we can take any two points on the line….point on a line let them be A &B.*

*G&S: Hmm..ok*

*R: So you can take any length of line segment AB on the line …. Like this [pointing to the segment AB on the line] …then we can draw a circle with length of radius greater than half of the length of AB. … then use this length and center A and B we can draw a circle … like our previous circle construction …ya*

*G&S: Ok*

*R: Now the two circles intersect outside the line …here [pointing to the location of the intersection points of the two circles] then we can use intersect tool to see the intersection*
point ...like this ...then we can draw a line passing through these points ...this line is perpendicular to this given line ...ya ..

G&S : I see ...

R: The same is true for constructing parallel lines ... or others by using our mathematics knowledge ...you can try ...ok?

The latter was a kind of rhetorical question to find out if they were ready to try to use GeoGebra by themselves and to start making constructions. I suggested that they could even start repeating what I had just demonstrated and then start making new constructions, for example from their list of topics:

R: Could you try to construct by yourself ... you can start ... So you can reconstruct the previous construction and then you can construct parallel lines and the next topics

S: How we can start...

The above reply shows that my demonstration of about half an hour was in their eyes maybe not enough. They needed an extra push from me. I decided to rearrange the setting: one of my colleagues would sit behind the laptop and would interact with the computer while his colleagues were next to him and I was standing behind them giving operational hints and motivational support. In other words, I forced one of my teachers to get started: Sebsibe was chosen by accident. But I made sure that this setting was still comfortable for my colleagues by my presence and by first letting them repeat the example shown. This was my strategy to get them into practice with GeoGebra.

When they constructed their own applets they were a little bit worried because they did not easily figure out the tools of the software to connect mathematical ideas and create applets. The following direct transcription was taken from their discussion and it illustrates how the teachers found their way:

G: I think we can use ...ok where is the tool...I think segment between the points

S: Connect the point not by segment it should be a line

S: May be segments
**G: Ok not segment I see...stop**

The above transcript indicates that my colleagues were struggling to familiarize themselves with the software and to discover the type of tools that can be used to construct applets. It indicated that they needed some support from me so I helped them:

**R: Ok let me help you ...select the line in the dropdown menu and you get the line menu and choose here** [pointing to choose the line tool from the dropdown menu item]...

**S: It is here ok oh ...this is what I have**

**G: Yes you are right**

The full discussion on this point illustrates their feelings by expressions like “Oh I found it” or “I got it” or “That is what I want.”

**Summary of the first day training**

On the first day of training my colleagues had reservations and they were uncertain about the educational benefit of the software. Besides they worried about mastering the tools of the software. Also when they easily got a result directly by selecting from the tools menu or by a command in the input bar they were questioning the value of student learning.

*You showed us by constructed line segment and circle. So what will [we] ask students if the software draws the line like this? What is the learning? What is the advantage of the software or what are the practices [for] the students?*

In sum, on the first day of training my colleagues were a little bit worried about the software and its applicability in mathematics education. They were like novices, a bit worried about the tools and constructing, and they struggled to learn and practice with the software.
6.1.2 Second Day of Training

The main objective of the second day of training was that my colleagues should develop skills and knowledge to construct applets using GeoGebra. My training strategy to develop their skills and knowledge of constructing applets was to give them full control and responsibility for the discussion and construction of applets during the training session. Throughout the discussion my training strategy was to encourage and motivate them to work independently and to think aloud. I believed this strategy would help them develop skills and knowledge of applet construction within a short period of time. During the discussions I worked as a discussion leader not directly involved in the discussion itself. In other words, I created an environment for the training that enabled them to try freely their own thinking and assumptions, and to use creativity for the constructions of applets with GeoGebra.

The setting of the training on this day was similar in arrangement to that at the end of the first day: Sebisbe voluntarily led the discussion. At the beginning of the training Sebsibe expressed his uncertainty by raising questions about the educational use of software. When he worked at home, he observed that, if the software gave the result without requiring students to think about their learning of mathematics, he thought that the students would not learn. He expressed the following concern by reading the questions from his handout about the educational benefit of the software:

7The handout is writing pad that teacher educators used to take some note like the commands and syntax of GeoGebra software during the discussion)

S: I have some questions I am a little [bit] worried about the use of the software when I try at home

R: Ya you can ask me ... go ahead

S: If I want to sketch the graph of $\frac{x^2+1}{x}$, I consider many things like asymptote, intercept, turning point, extreme point and also visualize what the graph looks like before I give the sketch. When I use GeoGebra most of these are missing. I give it the function in the input bar, it produces the graph! Where is the learning?
This indicated that my colleague Sebsibe was still quite worried about the didactical aspects of the software and its cognitive representation of a mathematical idea in students’ minds. He thought that the software might not allow or give students a chance to think about mathematics. In general, he was concerned about the students’ learning using software. Besides his concern about student learning, his question showed how much he was motivated to learn and to know by taking into consideration student’s learning of the software. Also he worked at home in his spare time.

He wanted to continue, so I agreed that he should ask his other questions:

*R: Ya you are right. Go ahead and finish your question*

*S: Another thing that bothers me is: when I give a task to the student I expect her/him to concentrate on subject knowledge but here… they have to struggle with understanding the working of the software. Itself, an additional job. Will that be time consuming and even frustrating?*

Gizachew raised his hand after Sebsibe finished asking the second question but I did not give him a chance to ask. I wanted Sebsibe first to finish his questions:

*R: Ok continue your questions. Let Sebsibe finish first and then we can answer your questions together*

*S: Ok my last question is how do I judge [if ] a poor outcome is a result of poor subject matter knowledge or lack of understanding of the software ?

*R: Do you have also another question….or Gizachew?*

*G: I think before to answer these questions first at least for our consumption let’s proceed for the training of the software. After that of course we can have other sub-questions related to… like psychomotor domain, cognitive domain, how to evaluate… but first let’s proceed.*

Before I commented on Sebsibe questions, I gave Gizachew a chance since he had raised his hand. But Gizachew understood that Sebsibe’s questions might be answered as they were working through the training. He thought that they might have many more questions about
different educational aspects of the software concerning students’ learning. This dialogue seems to indicate that the two colleagues had different working style preferences.

These questions showed that my colleagues had reservations about the software: for students’ learning, the educational usability, and the impact of the software on the student’s final performance. Beside their reservations and concerns for the educational usability of the software, both colleagues were engaged themselves to know, to discover and to learn about it. I decided not to answer Sebsibe’s questions immediately:

    R: I think I agree with G’s idea. S’s questions may be answered in our progress in the training time.

On both days 1 and 2 my colleagues’ main concerns were more on the technical aspects but they were also very motivated and interested to know all about the software. One of the moments that shows both their motivation and their progress in skill development follows:

    R: Ok we can start our today’s training. Who wants to lead the discussion?
    S: I may lead the training but before let me show you... I tried ... to construct some applets at home.
    R&G: Ok go ahead
    S: Well I didn’t work on the paper you gave. I just tried other methods. Do you want to see what I did?
    G &R: Ya ok
    S: What I did is this ...I tried a graph and it works nicely, and you can change the color and things like that. This one is a rational graph
    G: Ya it is a rational function
    S: I want to show you that it is possible to change color, thickness of the graph and so on ...

The above discussion indicates that my colleagues worked independently in their own way at home. They were trying to figure out some of the tools by themselves. Not only this, they were
discovering new tools like editing using color and changing the thickness of their graph lines. I did not ask them to try at home but they worked at home anyway in their spare time.

**Summary of second day training**

At the start of the second day of training my colleagues were almost completely reliant on their notes on how to use the tool and write some commands in GeoGebra, but at the end they started to figure out by themselves where to find the tools without going back to their notes.⁸

In the second day almost all the discussion time was fully controlled by my colleagues. They were very active and made good contributions throughout to the discussion. I was still acting as a guide and mentor. They developed some technical skills and knowledge of the software, and they were able to use their developed skills and knowledge to construct applets. They were able to explore more freely and learn more about the software techniques. They were also uncertain about the educational use but struggled to know the benefit of the software showing both enthusiasm and motivation.

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⁸Teacher educators took copies of my notes for the first day on what to do, when to find specific tools and so on.
6.1.3 Third Day of Training

The main objective of the third day of training was to develop my colleagues’ skills and knowledge on how to construct applets and to show them how to represent their mathematical ideas using GeoGebra. The setting of the training was similar to the previous days, but today there was a change in who led the discussion. The swapping of the role of discussion leader was created unintentionally when they each tried to contribute their own ideas. My general training strategy was similar to that previously used; I used collaborative-sounding input to help them to develop skills and knowledge to construct applets. Before the discussion began, Sebsibe talked about what he found when he was searching the GeoGebra web site:

*S*: Today I saw a full course of calculus applets constructed with GeoGebra. I tried to open it... I couldn’t open and many people also commented on this problem on the internet. ... I see it [is] called java ...I do not know... I think if you design applets and [give them to] the students, if the applets do not open then it is a problem. So we have to think about it and is there a way out?

*R*: I think there is a solution. From my experience I also got this type of problem but when I updated the java applets with the newest version, most of the time it worked. But you are right we should have to think about it.

This indicated how much Sebsibe was motivated and eager to know the software. Here one can easily elucidate how my colleagues were engaged by themselves to discover, explore, search and investigate information about the use and applicability of the software from supplementary sources like the internet.

So at this point one can notice a shift of thinking in my colleagues on the educational use of GeoGebra when compared to the first day’s meeting; they now seemed more certain. The discussion setting was more or less similar to that of Day1 and Day2. At first Sebsibe led the discussion but inbetween Gizachew took over the leadership role. They showed much more confidence and acted in a collaborative manner:

*R*. You can start from what you know or choose one as example

*S*. Hmm hmm ...ok for instance let us take the sequence of Fibonacci to create
R. Oh no let start from the simple one like sequence which lists [a] sequence of numbers.

G. S start with a simple one...then we can create the element of the Fibonacci sequence...

S. Ok let’s start with 5 and let the sequence be given as $a_0, a_1$... Let’s say this $a_0=5$ then $a_n = 4 + a_{n-1}$... wait me... let’s say $n=1,2...10$

S. How can we do that? I think there must be a rule .... I have a book let me check for the rule...

G. Ok...ok ...

S. I think I have it here. My reference book is here in my office let me check it ....

Here there is a clear indication that my colleagues were developing skills and knowledge to construct applets by using GeoGebra. Also, they were clearly focusing on mathematical ideas they wanted to use. They started to manipulate the tool of the software but they were still a little bit uncertain how to represent their mathematical ideas. For this they were seeking for some help. I helped by giving a hint:

R. Can I give hint for you ...?

S&G. Of course ...

R. You can list a sequence of numbers from 1 up to 100, and has difference 4 and you can write expression like this...

S. How do you separate?

G. I think the difference is 4 ....

S. Where do we write the rule?

R. You can write here [pointing into the input bar ] in the input bar like this.

G&S. Is there a function sequence?

R. Yes... it has; can I do one for you ?

S&G. Yes show us....
R. For instance you can write sequence[(i,4+i),i,5,100] you can get this list of points

S&G. I see ...hmm...ok

Again they had clearly made some progress. They acted more as experienced users of the software, and they did not care much anymore about how to figure out the tool of the software, but instead cared to represent their ideas using it. They still struggled a little bit to represent their mathematical ideas. They questioned more about how to create mathematical objects for their mathematical concepts or ideas instead of worrying about the use of the software. I worked here collaboratively with them and my involvement changed from demonstrator to more guide and mentor. My role and their role had completely changed when compared to the first day’s meeting. For example, Sebsibe suggested his own idea for the construction of applets:

S. What happens if I have a sequence and suppose I want to find the 25th term? Is it possible to get this result using the software?

R. I think it is possible and it works...

G. I think we can... let me try ...I think it is finding the corresponding values? Ya

S. Ok let me try ...what can I do ...I can say sequence[(i,i+4),i,5,25]

At this point my colleagues were trying to construct applets using GeoGebra that represented their thinking about a mathematics concept. I commented on their suggestion to think about the logical order of an applet’s construction for the concept:

R. I think this formula will not give you the result but it will list for you all 25 values. In my suggestion I think first you have to list the element first and then you will choose among them.

At this moment they tried to do things in their own way, but they did not succeed to construct the exact applet that they wanted. Then they started analyzing and thinking about their work. This shows my colleagues had developed some skills and knowledge on how to construct applets, but they still had a little bit of difficulty to connect logically their construction with the mathematics ideas. They wanted some help from me, asking why their way did not work. I tried to draw them out:
G. I think this may not work ... I though it is easy but let me think ...

S. Among the list you mean? But that will be a problem.

R. Why?

S. Why because it is a problem ... because you may not want to list all the terms ... I only want to pick up the 25th term.

G. I think it is difficult ...

R. Ok let us try ... that is my suggestion

S. It should work ... say I have a sequence, sequence [(I,i+4),i,25] only I gave the first term 25

G. What about this one... the end value ...

S. Let us say enter "enter"... it says illegal number of agreement ... ok ok that will do ... it does not work

G. I think ... say I...what about this one ... try for the end values

S. I gave it but it gives you the list of 25 numbers ...

G. Is it possible to get these ... it says increment start value...end value and let’s give the start and end value the same value ...

S. I think this work ...hahahahaha....

R. Ya but we should have to be logical .... It will give you the term value and the result but that is not our [desire]. We want the function to pick us [out] the 25th term value among others ya...

G. Ok let us try ...

At this point in the training both Gizachew and Sebsibe were now playing and exploring with the software using trial and error to represent their mathematical ideas. I suggested to them to be logical as I wanted them to think and connect their ideas. I wanted to show them that the
software would not give them results unless they wrote logical commands. I pushed them to think about their sequence of commands and they agreed and took my point into consideration.

*R. Let me show you ... you see... using this formula first list the elements and select from the elements using the element formula of sequence*

*S&G. Ok ...ok ...*

From the above discussion one could understand that we were working together collaboratively and thinking independently at the same time. My colleagues were very independent and creative to construct applets using the software for the mathematics concepts. The discussion was free, and as can be inferred from the various dialogues provided here, it was obviously comfortable for them to contribute their own ideas. Here I worked as a colleague or sometimes as catalyst of our discussion. They were concerned by the mathematical concept representation using the software. At this time they were still a little bit worried about this last point.

**Summary of third day**

Some of the moments during the discussions in third day show that my colleagues were developing a firm understanding of the educational benefits of the software, but they still had some concerns about how to present the material to their students.

We were working collaboratively in the construction of applets. Our roles had all changed: I had become a participant and still a catalyst in our discussions, while they had became comfortable users of the software; also they had begun to try using it to illustrate particular mathematics concepts. At this point they showed they were able to create applets and could connect their mathematical ideas to create a mathematical object with the software.
6.1.4 The Fourth Day of Training

The main objective of the fourth day of training was to develop further my colleagues’ skills and knowledge of how to construct applets, and to show them how to represent their mathematical ideas using GeoGebra. The setting of the discussion was similar to previous days, and both of them contributed equally to the discussion. During the discussion time I gave them more opportunity and more freedom to try their own way.

S: Say for example if we ask students for \( a=-1.7, \ w=0.2 \) and \( A=2.7 \) for the equation \( y=A*\sin(a*x+w) \). We can ask them What is the period? What is the amplitude? What is the frequency? Things like that can be asked and the student can read this value from the graph.

G: Hmm ... I see we can ask like ...

R. Yes it can be asked ... they can answer or say some things. You can also do for cosine function.

G. It will be the same as the sine function it may have shifted by certain...

S. Yes it is the same....

S. For the students to see the difference in phase shift you may partition the x –axis in to \( \frac{\pi}{2} \) interval instead of \( \pi \)... it will be fine.

Here my colleagues were using GeoGebra to represent their mathematical ideas visually to their students. They now believed the software could be used as a visual aid for teaching mathematics. At this stage their concern was on the finished product of their construction and the visual effect of the applets for their students. All this shows how comfortable they were with the software.

After this dialog they discussed the visual effect and the graphical representation capability of the software:

S. When \( A \) is zero the graph is disappeared you see

G. Ya ya...you see

R. You can ask students why the graph disappeared when \( A=0 \).
S. Yes we can ask ... you see from the graph ....you see some kind of crazy things comes out... alright it is very nice!

G: I think you can use it in physics to ask [about] oscillating things ...

Here it is clear that they were just playing with the software and no longer at all worried about finding specific tools, but certain of the software’s educational usability. They were exploring more and discovering different applications. They started to create connections of mathematics topics with other fields like physics. This indicated that they had developed firm skills and were in command of the software.

Summary of Training Phase

By the end of the four days of training, my colleagues had become competent explorers of the software. Their doubts and uncertainties about its educational use seemed to have disappeared. They could choose a new tool and in a short time be competent in its use. How to figure out some of the tools of the software was not a problem. They were more comfortable to construct applets with GeoGebra for mathematics concepts, and they could represent their mathematics ideas well. Evidence for these findings is found in the interview at the end of the training phase:

R: What do you think about using GeoGebra to construct applets?

G: I have taken the training with you about GeoGebra. I have a better idea now than I had in the first day training. I thought the software was just like any other mathematics software like MatLab & Mathematica but now after going deeply into the GeoGebra software I have seen it is a different software and with a different approach when I compare with the other software. It is a software which really gives to the teacher trainer and also for the students a very good learning environment which gives more chance to the students to develop, to discover, to construct a mathematical knowledge by their own effort. Of course that effort should be very carefully guided by the teacher in the lesson development and in the applet design in this case.

S: It is very useful for constructing applets and mathematical objects. It is free and useful for drawing graphs and show what you are thinking graphically. I am thinking we can use it for any mathematics course. I think it is very nice and we can use it for any course. For instance we can also think to use it in number theory. I am not sure for statistics
[but] I think it has some possibility. It is free and interactive to draw and construct mathematics idea. The software is attractive and the tools are simple to use and to draw any mathematics idea. It helps the students to think and [be] creative this makes the students active. I think there is a room for creativity.

These comments indicate that my colleagues were not only satisfied with the training but also thinking ahead. They had developed ideas about how GeoGebra might be used for teaching mathematics. It was clear that their views of GeoGebra as an educational tool had changed from the first day.

R: What is your impression so far of this ICT tool? Did you get new things out of this training?

G: I was very much impressed. I am a teacher trainer I teach mathematics methods of teaching to my students but I teach using lecturing methods. I know theoretically the constructive way of teaching but I teach… my students in behaviorist way of teaching so I think this training with GeoGebra will shift my future of mathematics teaching and it has also a positive effect on my teaching.

S: One thing I like the software. You can do anything with this software to construct any idea from calculus, geometry and algebra at the same time. I know some software that works only for algebra or geometry but this software has the desire[d] combination and the most important thing is this software is free. It is very important for us to have free software which [is a] practically powerful tool.

Here Gizachew seems to be rethinking his lecture style of teaching and beginning to consider a more constructive approach. Sebsibe, on the other hand, focuses on how GeoGebra can be used among many areas of mathematics, and importantly for his situation that it is free software.

R: What did you think of this type of construction of a mathematics concept using GeoGebra? It is easy for you to construct mathematics concept using this software? How? Can you explain?
G: It is very much helpful even not only for the student but also helpful for the teacher himself. With the software you can create very interactive applets and lessons...very carefully to give to the students. The students will have better chance to learn and the teacher will also save energy and time. The knowledge developed by the students in this way will not be easily forgotten and hopefully I will use this software to construct on my lesson in the future. In the future this lesson will be part of my lesson.

S: The software is easy to learn easier than most and I [am] thinking it helps the teacher to construct an activity to visualize concepts or ideas to the students. Using the software, teacher can construct worksheet and activities that promote [on] activate way of teaching. It is helpful to prepare a handout to give or put as reference for the students when the need arises before the class begins.

In summary, at the end of the training phase both colleagues had reached a point of being very comfortable with and quite competent in using of the software. Furthermore, they were now thinking deeply about how students’ learning could be positively affected if GeoGebra were used to teach mathematics.
6.2 Development Phase

The development phase had four parts. Part I: Lesson study of others’ lessons, Part II: Designing activities and constructing applets, Part III: Testing with a selected group of students and Part IV: Planning their research.

6.2.1 Part I: Lesson Study of others’ Lessons

In this stage, I showed my colleagues how three people had used GeoGebra with secondary school students. The main objective of this lesson study was to show them the different style of instruction and possible group setups in student-centered instruction. The other main objective of watching others’ lessons were to show my colleagues an example of how a student-centered way of teaching can be taught practically in a classroom. I decided to begin with my Winter Project (Section 4.1.5 and 4.1.6) because the computer lab setup of my class was relatively similar to their computer lab setup. I thought this would help them to develop a mental image and to relate easily what they saw in the video to their own computer lab room. First we looked at one of my lessons (Tessema, 2011) which was developed and taught in the Netherlands to Dutch students as a small research project in my master study. The aim of showing this project was to show them how one could try out and research student-centered material using GeoGebra. Secondly they did a lesson study of Wakwinji’s Winter Project (Wakwinji, 2010). I chose this example because it has both some similarities and differences with my lesson. I thought it would help them to see different styles of group formation in student-centered instruction. Finally they learned about Mainali’s master research project (Mainali, 2008). The main objective of looking at photographs and examining his instructional materials was to begin a discussion on how student-centered instruction could be implemented in a situation similar to that in Ethiopia.

Lesson Study from Tessema’s Winter Project (2011)

My Winter Project lessons were designed and taught at secondary school in Amsterdam, the Netherlands (Tessema, 2011). The discussion began as follows:

\[ S: \text{In your lesson I have a question?} \]

\[ R. \text{What is your question? Tell me…} \]
S. Here you have given to them using square root value but they can’t do it here [Referring to question number 6 in activity 1], so isn’t it better to have either some kind of conversion here from square root value to decimal value?

At this point my colleagues started to be critical about the lesson design. They suggested some improvements in the activity. On the whole they thought that it was a better way to present mathematical concepts for student learning:

R. You are right it requires them to work on the conversion, but when I constructed this I considered their educational background. Most students have already learned and know about the decimal approximation of square root values so I took [this] into consideration when I constructed the applets and its values.

G. Ok that is the reason…. They also work on the arithmetic part of the mathematics Ya... I see

S. Ok ok....

My answer also gave them a hint that it might be important to consider students’ educational background when developing activities.

Figure 6.1 A Picture taken from video of Tessema’s Wintor Project (2011). Showing students were helping classmates.
G. You see from the video they are free ... you see that boy he move from one group to
the other ... it is nice . it is so surprising...you see your students are active ...your
students work independently and you see how they... discussed with each other  ... ho ho
ho ... it is really nice way of doing ...”

S. They are happy ...it is looks nice

They were very impressed and surprised by what they saw on video. This was their first time
observing students working freely and discussing in groups in a class. At this point my
colleagues began to develop a mental conception of how active learning practices might work in
a real classroom. This was seen in the interview after the video.

R: What does student-centered teaching mean to you? Did you observe this in the video
practically?

G: I understand student center teaching...it is a type of teaching-learning process which
gives more chance to students, to discover, to discuss, and to engage actively than other
ways of teaching. It is more interactive type of lesson, more engaged type of lesson. It is
just like a lesson that I saw in your video in the Dutch school, and it is typical example of
student-center approach teaching.

They knew theoretically about the meaning of student-centered instruction, but not how it could
work in practice. They began to find out about this by watching the video. This indicated that
the video worked as a kind of lesson study for them to develop a mental conception about the
practices of student-centered instruction.

R: What was your impression when you see students working in group?

S: Oh well,...working in a group in this kind of activity is very useful because for one
thing it helps the learning process and with minimum computers because you can use one
computer for three or more students not just for one student and it also they can share
ideas so one student will benefit from other students when they are working in groups..the
lesson develops interpersonal relationships when students learn using this way of
teaching.
From the above comment one can easily understand that my colleagues knew the importance of working in groups. They believed group work has advantages for students “to share knowledge”, “to get benefit from each other” and to “develop interpersonal relationships”.

*R*: Can we construct this type of lesson to students that learn in Addis Ababa school from what you have seen in the video from Dutch schools?

*G*: Do you mean to create designing lessons...ya sure it is very much possible and teachers have to or should also start doing that I think. Teachers have to stop and think this type or style of a different approach teaching. Because we cannot continue always teaching mathematics using only lecturing methods. We should also start to adapt this way of teaching I think. So yes you can take the student text book and produce sample applet and lessons and there are even some schools which have computers so we can practice in some schools in Addis Ababa.

The main reason for this question was to enable them to consider the possibility of using this instructional method in Addis Ababa schools or in their own class. Their answer indicated that they thought there was a possibility of using this type of instructions even with limited resources.

*Lesson study from Wakwinji’s Winter Project (2010)*

My main objective here was to show a different style of instruction and group setup as an example of student-centered instruction to my colleagues. During this time my colleagues focused more on criticism of the designed activity. Again they suggested recommendations for change or improvement of the activity from the perspective of student learning:

*G*: How [will] the students work with this problem here [referring to the students worksheet: activity 2]... they will work on the paper or GeoGebra?

*R*: I think for the table they will work manually and then they will use GeoGebra for plot the graph

*S*: What is your thinking when you ask this?

*G*: I saw instruction on the first activity worksheet and it said for the students to work first on paper and compare with their work after drawing in GeoGebra but here it did not say anything. Is there a plotter or curve tool in GeoGebra that used to connect the
point after plotting the point? It is not clear for me what the students will work on in question 5b&c [Appendix, Wakwinji., 2010 lesson study material]. I think there must be clear instructions here [referring to the worksheet of activity 2].

S: I think they can use the table to plot the graph ...ok?

R: I think here ...the teacher may think the students work on the paper ...it is not clear for me too ...

Their suggestion reflects here their critical thinking about how the mathematical tools provided could affect students’ learning. They suggested that from the point view of student learning “there must be a clear connection between the tools that we provide as a means of constructing to the information that is provided in the lesson activity”. After this discussion I again interviewed them. Note that here they often refer to both lessons seen (Tessema, 2011; Wakwinji, 2010)

R: What is your impression on the two lessons?

G: Ok ... what impresses always is the responsibility that is left to students in both lessons. The students are given more responsibility to learn by their own. I have seen the teachers simply coaching, guiding and presenting the activities but the majority of the work is given to the students...themselves. So they are expected to discover mathematics or we can say they are expected to construct the knowledge by their own effort which is a little bit supported by the teacher. That is what I observed from the two lessons that I have seen in the video. This impressed me because more responsibility is given to the students themselves in the lesson.

There were clear indications that my colleagues found the video records of students’ actions interesting. They were critical, yet they also understood the different roles of the students and their teacher. Not only this, they understood how a student-centered way of instruction could help students to construct their own knowledge.

R: How did you see the teachers and the students’ work on the two lessons? Did you see some similarity or difference from the above lesson? What is that, can you discuss?

G: Well actually the similarity is much more in the two lessons than the difference. For instance in the first lesson we can see the students working in groups and also their
teacher helps them during the lesson and it also true in the second lesson. They are more similar than difference. But I observe [a] difference in the setting for instance in the first lesson students only have one computer in one group but in the second group the students have their own laptop and as well they were working together

At this stage my colleagues tried to distinguish between the two lessons by the different group setups. From both lessons they observed the possibility of different arrangements of groups. This illustrated that my colleagues understood that there could be different group formations in student-centered instruction.

**Lesson stud from Mainali’s master research project (2007)**

The main objective of observing the pictures and lesson study material from Mainali (2007) was to show my colleagues how he was able to implement student-centered instruction in a situation similar to that in Ethiopia.

*G: What did he give them ... there is no GeoGebra I mean there is no computer? They are not using this software

*S: I think he printed the activity and gave them

*R: Ya ... he gave them the printed activities and he projected the GeoGebra applets using a projector ...do you see this picture [referring to the pictures in the lesson study material]*
The picture shows students actively participating during the lesson.

G: Ok I see.. the activity is given to the students ...good

S: I think what he did ... he prepared the activity and he designed the applets and then he projected the applets using projector...

G: He used only one computer and projector...ok ...

At this stage they expressed their thinking about how Mainali (2007) was able to design the lesson by asking a rhetorical question like “how did he manage to practice student-centered instruction with limited resources”. But they could understand the classroom setup and how he could also practice student-centered instruction. This shows they were developing a mental conception of how to create student-centered learning with limited resources and large class sizes:

S: Hmm.. it has merit ...I mean it looks more like our situation...we have about 40 to 60 students in class and we do not have enough computers. We [keep] on doing on black board ...I think this is profitable for us.

At this stage they started to create a connection from what they observed from the picture to their current situation. They expressed themselves by saying “it is possible” and “helpful to practice”
this style of instruction. This indicated they developed a mental conception of the possibility of practicing student-centered instruction in Ethiopia with limited resources. I interviewed them to explore their ideas:

*R: Is it possible to construct and implement student-centered methods of teaching with limited resources and with a large number of students?*

*G: Ya, yes is my answer. This is typical lesson that we sometimes practice also here in our class. We have got a lot of students in class I mean [a] relatively large class size but very limited resources but still we try selected topics of mathematics lesson to treat them in more or less similar way as the third lesson was treated. The answer is yes, it is possible to construct and implement such kinds of lesson; I mean a student-centered way of teaching with very limited resources that we have. I also I remember topics in high school mathematics that I have tried with limited resources to make a little bit student-centered way of teaching... For instance I remember I tried to teach students with limited resource in Geometry class to construct using paper and to dismantle and try to understand and discover the area of prisms and solid figures.*

They related what they saw in the photographs to their current situation. This illustrates that even a picture could help them to develop a mental view of how student-centered instruction could be done even with limited resources. They also reflect further on this possibility.

*R: Is this is possible in an Addis Ababa school situation or at your institution?*

*G: Yes it is possible to implement this type of lesson in Addis Ababa or in our institution even if we do not have GeoGebra or computer. Well, having computers and GeoGebra will make our lesson best, but we can also construct such kinds of lesson in our institute or in Addis Ababa schools with limited resources.*

*S: I hope we can practice this type of lessons but this maybe depends on the teachers’ motivation and their knowledge to practice this type of lessons. It is possible I will try my own lesson in the future.*
Summary of the Lesson Study Work

The lesson observations helped my colleagues to develop a mental conception of what student-centered instruction looks like in a practical sense. Their comments and suggestions for the other instructional materials might help them to develop knowledge of what to consider during applet construction and activity design. They now seemed able to construct applets by taking into consideration students’ background knowledge. By watching videos and observing pictures they acquired knowledge of how active learning instruction can be put into practice. In general the lesson studies worked as benchmarks for my colleagues to develop a mental conception about how student-centered instruction can be practically implemented in a classroom, even with limited resources.
6.2.2 Part II: Designing Activities and Constructing Applets

In this section I briefly describe the topics that my colleagues suggested, and how they designed and developed their own lesson materials based on their topic, and finally how they constructed applets and tested the designed lessons with randomly selected students.

**Topics suggested by the teachers**

After looking at how others have used GeoGebra, I suggested that my colleagues would think about their own lesson design. I also proposed that they would bring their own topics, objectives of the lesson and their own ideas to develop the lesson material. Accordingly both did this:

Sebsibe suggested a topic from his course outline “*Exponential functions and their graphs*”. His main reason for choosing this topic was that from his past experience most students failed to understand it easily. His aim was to see how easily students could understand the concept of Exponential functions and their graphs by learning with the help of GeoGebra.

Gizachew also suggested the topic of “*Algebraic sign of sine, cosine and tangent function.*” Gizachew thought from his past experience that most students have difficulty to understand and come up with a general solution for the sign of sine, cosine and tangent functions when the angle is greater than $360^\circ$. His aim was to see how learning with the support of GeoGebra might enable students to generalize and conclude on a topic like this on their own.

**Developing lesson material and constructing applets first session: Gizachew’s draft lesson**

Together we discussed the applets and activities developed by my colleagues. First we discussed Gizachew’s activities and applets (Appendix D):

\[ G: I \text{ tried like this } \ldots \text{ you can comment...} \]

\[ R: \text{ We can comment together....} \]

\[ G: I \text{ constructed this right angle triangle.} \]
Figure 6.3 Gizachew’s Applet for asking students background knowledge about definition of sine, cosine and tangent functions

R: what is your thinking when you constructed these applets?

Here my question was to find out his thinking when he constructed his applets; his reply shows that he took student’s background knowledge into consideration.

G: I want to ask them this question as a revision. It will help them to revise their previous knowledge about the relationship of opposite, adjacent and hypotenuse sides of right angle triangles to define sine, cosine and tangent.

R: Ok I agree that is possible ... it is a good idea and what about the other applets

G: These applets are used to ask students to identify the sign of sine, cosine and tangent in the 1st, 2nd, 3rd and 4th quadrant. The second applets I made with the slider interval by 30° with total interval length 2𝜋 and for the third applet I made the slider for any angle. In the first activity I will use applet I and II and in the second activity I will use applet III.
Figure 6.4 Gizachew’s Applet I: For angle $\theta = 30^\circ, 60^\circ, 90^\circ \ldots, 360^\circ$

Figure 6.5 Gizachew’s Applet II: For any angle $\theta = 0^\circ, 1^\circ, 2^\circ \ldots, 360^\circ$
Figure 6.6 Gizachew’s Applet III: For any angle $\theta \geq 360^\circ$

R: Ok ... Why do you use the interval length $30^\circ$ in the first applet? Why not other angles? What about the third applet.

At this stage my question shows I wanted to know more about his critical thinking when he designed his activities and applets.

G: I simply bring it for the student to try out...as an example because most of them know about it. They know the sign value of sin$\theta$, cos$\theta$, and tan$\theta$ for $\theta = 30^\circ, 60^\circ, 90^\circ, ..., 360^\circ$. I think this is simple for them. I know most students in my experience they couldn’t come up with a general solution for any angle $\theta$ greater than $360^\circ$. This is what I want to ask in the third activity ... that is why I made the applets for any angle.

R: Ok that is great ... ya you are right ...

Gizachew seemed comfortable with his designed lesson material but some editing was needed of both the activities and applets. After discussing with Gizachew, we continued by examining at Sebsibe’s activity design and applets.

**Developing lesson material and constructing applets first session: Sebsibe’s draft lesson**

S: I tried this ... I design first the activity and I construct this applet
Figure 6.7 Sebsibe’s first trial applet on exponential functions

R: What you want to ask… your students?

S: I want the students to know the property of the exponential function … I use two different bases … you see here slider $a$ is between 0 and 1 … and the slider $b$ between 1 and 2…so the students will know the property by sliding

R: You are right …but as you remember when we discussed last time you told me… you want your students first to define the exponential function …ya

Here Sebsibe’s applet construction did not fit with his ideas about the activities. At this point it seems that Sebsibe had not considered student’s previous knowledge for connecting past experience with new knowledge.

S: Yes…Yes you are right

R: So in my idea … this activity … I think we should ask them finally… I do not have any problem with your construction … I agree but …

S: So what you will suggest … ok let me think. I think it needs time

R: You are right … ok let us meet for Thursday?

S: That is possible…ok
At this stage Sebsibe needed some time to think more about the structure of his activities and constructed applets.

**Developing lesson material and constructing applets, second session**

We met to discuss and finalize my colleagues’ activity designs and constructed applets.

*S*: This I constructed ...

*R*: Ok...What did you think when you constructed these applets for your activity?

*G*: Let me see it ... what do you want ask students? To draw the graph or ...

*R*: I think there must be additional activities that help students to come up [with] the definition of the function.

*S*: No no ...I am thinking like this ... I will give this applet to the students and the students will use the slider and by sliding they will see the change of the graph like this ...then they will know the property.

*R*: My question is ... I think you want your students to come up by themselves with the definition of exponential function based on the constructed activity, and then they will use this applet to know some of the properties of exponential functions. I think you ...

*G*: I think if you want to ask your students this question ... I think as background knowledge we should assume the students know intuitively the definition of exponential function... if so, you can ask this question

*S*: So what do you suggest ...

*G*: My suggestion is...give detailed information about the exponential function and then ask them to know the property ... I think like this

*S*: Let’s first finish and we can modify after that...

Here Sebsibe shows resistance to changing his idea about the applets but after our discussion he agreed with us about the applet. Our suggestions helped Sebsibe to develop his thinking to consider the educational background of students either as revision or as an introduction to their new learning.
R: I already agree with your applets and activity ... I think there is no problem ...

G: I think so ...

This shows our collaborative work helped him to think in a way the lesson activity might be designed.

**Summary of Lesson Development**

At this stage my colleagues had developed their own lesson material and learned that critical discussion on the designs had helpful consequences. Before directly using their developed lessons for research, they planned to test the constructed applets and the designed activities on randomly selected students as a pilot study.
6.2.3 Part III: Testing with a Selected Group of Students

The main objective of the pilot study was to see whether or not the designed lesson material and the applets helped students to understand the main concept by themselves without direct teaching of the lesson. The other objective was to update, modify, edit and make ready the lesson material for the actual student group to use. Both Gizachew and Sebsibe were curious about students’ learning: “will students easily understand this lesson only by presenting the lesson material and the applets in this way?” They repeatedly asked this question before implementing the pilot study. Here I outline first how the Gizachew’s lesson went in the pilot study and then Sebsibe’s lesson.

Gizachew’s Pilot study

For the pilot study my colleagues randomly selected eight students from first year diploma program mathematics students (Section 3.3). The selection was based on student volunteers to participate in the pilot study. The first four students among the eight students were asked to come to Gizachew’s pilot study and the other four students were asked to come to Sebsibe’s pilot study. During Gizachew’s pilot study one student was late. So because of this we used only three students’, by accident all three were male.

Figure 6.8 Gizachew’s pilot study: Students working with the activities and Girachew observing.
During Gizachew’s pilot study at first he was very anxious because he thought students would not work independently without his help, but later when he saw students working independently with minimal guidance, he was surprised at how his new lesson went and how the new instruction helped students to discuss with each other. He told me that the pilot study helped him to develop confidence in his new way of instruction, and of its greater helpfulness for student learning than his previous instructional practice.

**Sebsibe’s Pilot study**

During Sebsibe’s pilot study we got five students. The number of girls was four. This was not planned. The reason was from the eight students selected for the pilot study, we used the first three for Gizachew’s pilot study (those who came on time), and we used the rest for Sebsibe’s pilot study (those who came late). The number was the main difference we saw in Sebsibe’s pilot study compared to Gizachew’s pilot study.

![Figure 6.9 Sebsibe’s pilot study: Students working in a group and their teacher giving some instruction](image)

Figure 6.9 Sebsibe’s pilot study: Students working in a group and their teacher giving some instruction
Summary of Colleagues’ Findings from their Pilot Study

The pilot study results helped my colleagues to see in a practical way how students might work in groups, how students helped each other, and how they could think independently. It also helped the teacher educators to develop confidence and motivation to practice this style of instruction with students. The pilot study results helped them to see practically what active learning means. It also helped them to update and edit their instructional materials to use for their actual research. For example, Gizachew made a minor change in his lesson sheet (Figure 6.10).

![Figure 6.10 Shows minor change in Gizachew activity sheet after the pilot study](image)

After pilot study
Gizachew updated the \( \sin \theta \) into \( \cos \theta \).
6.2.4 Part IV: Planning their Research

In this section I describe how my colleagues developed their own research questions and research instruments to collect data.

**Research question design**

After some discussions of my colleagues ideas for research questions I sent an e-mail to my adviser Dr. Mary Beth Key to get her comments and advice regarding the planned research question. The development of the research questions is shown in two e-mails.

“Dear Mary,

The following research questions are suggested by the teacher educators.

**Research questions from Sebsibe:**

1. Do students motivated when they are learning exponential function using GeoGebra software?
2. What is the effect of teaching based on GeoGebra on the students' understand the concept of Exponential function?

**Research questions from Gizachew:**

1. Is the new way of teaching with the help of GeoGebra applets will encourage and motivated students to learn better than the usual teaching methods?
2. Do the students show different or unusual experience when they learning using GeoGebra applet?

With best regards,

*Amdebirhan*” [e-mail date: 2-3-2012]

The reply came:

“Dear Amdebirhan,

So, I see that your colleagues are very independent thinkers!! I see this because they each have their own research questions. As you know I value independent thinking so I do not view this as a particular problem.

May I suggest some minor changes to the planned RQs? First though, I really think that two RQs is one too many for a small project. With this said, however, they could still
Sebsibe:

1. **To what extent are** students motivated when they are learning exponential function using GeoGebra software?

This is a good question to research. A positive answer will motivate the researcher to continue; a less positive answer will motivate the researcher to improve something.

Explanation: The original RQ requires a yes/no answer; the change 'to what extent are' allows for a variety of answers and it requires more description from the researcher. The last is just what one aims for in a small case study research project: in this kind of research more is learned in-depth about a small cohort [number of participants = cohort].

The yes/no version invites the following: Researcher: YES the students are motivated. Critic: OK, so they are motivated. Is each student motivated? How motivated are the students: some, more than usual, quite a lot, a lot???? [The researcher may not be able to answer these smaller questions from the critic because he has not collected the right kind of data.]

2. What is the effect of teaching based on GeoGebra on the students understand the concept of Exponential function?

This question is the kind that teachers want answers for. However, for a researcher **this question is simply not answerable** because it is too broad, and there will be insufficient data to support any answer.

How does Sebsibe define "effect of teaching"? Also, how does he define effect and how does he define teaching?

How is students' understanding going to be measured? [If it is that students can do a problem correctly, this will **not** give the researcher any concept of students' understanding.]

What does Sebsibe mean by "understanding", what is his precise definition????

Gizachew:

1. **In what ways does** the new way of teaching with the help of GeoGebra applets
encourage and motivate students to learn about sine, cosine and tangent functions? 
This is a nice question. The slightly adjusted formulation will enable the researcher to find out if students feel encouraged to learn, and whether they exhibit signs of being motivated. He might feel inclined to explore with his students these aspects of encouragement and motivation. Lots of scope for the researcher here!

2. Do the students have different or unusual experiences when they learn by using GeoGebra applets?

Another nice question! The researcher is probing his intervention by asking his students!! The researcher gives his students an opportunity to tell him what they think about the intervention. In turn they will have the feeling that their opinion counts. This is not on the point of the research, of course, but it is helpful for further experiments. [We must always have students' cooperation for something new.]

In addition, the researcher can find out just how students find things different and/or unusual. Of course, he should be prepared that a few may not view this in a positive light!

So, although this is apparently a yes/no question, in reality it is not quite because to answer it a description of students' experiences is required. So it is a deeper question in disguise! Good.

I hope this helps.

Best wishes to you, Sebsibe and Gizachew!

Regards,

Mary”[e-mail date :5-3-2012]

After I received this e-mail I discussed with my colleagues about the suggested research questions from my adviser. I explained her suggestion to them what it means from research point of view. They thought the suggested ideas from Dr. Mary Beth, could be researchable and answerable from the data that would be obtained from observations questionnaires or interviews.
Sebsibe updated his first suggested research question:

To what extent are students motivated when they are learning exponential function using GeoGebra software?

Gizachew also updated and changed his first suggested question:

Do the students have different or unusual experiences when they learn by using GeoGebra applets?

At this point my colleagues had first developed their own research questions after looking at the results of the pilot study. Both wanted to research and see how GeoGebra and the designed activities would help students to work independently and to understand the mathematics concepts without direct instruction by the teacher. They received some advice which helped them each to choose one to use in their small studies.

**Development of Research Instrument**

Next my colleagues developed and designed their own questionnaire and interview questions to use in their research. They planned to use the questionnaire, interview and their observation notes as data sources.

**Questionnaire Design**

The main objective of the questionnaire (Table 6.1) was to collect data about the students’ opinion of learning with GeoGebra. So the questions focused on investigating the opinion of students on how they thought the uses of GeoGebra in teaching mathematics affected their learning. Both colleagues used the same format and similar questions for their questionnaires. Specifically they thought that for both lessons they wanted to find out the students’ impressions, opinions and motivation about their learning with GeoGebra.
1. Did you like learning to solve sign of sine, cosine and tangent functions (exponential functions and their graphs) with GeoGebra? Please give your reason for or against.

2. What aspects of GeoGebra applet did you like the most? List and give your reasons.

3. What did you like most when you are learning the sign of sine, cosine and tangent functions with GeoGebra compared to learning with traditional teaching?

4. Please write down your general impression of learning the signs of the Sine, Cosine and Tangent functions using GeoGebra.

**Table 6.1 Colleagues’ Students Questionnaire**

**Design of Interview question**

My colleagues’ main objective in their interviews was to collect data about the students’ opinions and impressions of learning with student-centered instruction. The same interview questions were used for students in both classes.

1. Did you like learning mathematics with GeoGebra? Please give your reason for or against.

2. What was your new experience when you learned by using GeoGebra? It is easy or difficult to learn mathematics using GeoGebra. Can you explain how it is?

3. Working in a group is helpful. How it is helpful? Can you explain how?

4. Did you like the activities that designed by using GeoGebra applets? How it is helpful for you?

**Table 6.2 Colleagues’ Interview Questions for both Groups of Students**

**Summary of research questions and research instrument development**

At this stage my colleagues understood how to develop a research question that could enable them to reflect on their own teaching as well as on the students’ learning in mathematics. From our discussion and my adviser’s suggestions it seems they got a lesson in how to design a research question that could be researched and answered. They also developed skills and knowledge of how to design research instruments as a means for data collection.
6.3 Implementation Phase

My colleagues planned to implement their lessons for two periods on consecutive days in the computer Lab.\textsuperscript{9} During the first day, they split the first year students into two groups. The grouping of the students was done randomly by asking who wanted to attend the earlier class. Students did not know who would be teaching. They used the first twenty-four students for Gizachew’s class and the remaining eighteen for Sebsibe’s class. Gizachew implemented his lesson first while Sebsibe was an observer. They used this arrangement also during the second lesson, with Sebsibe teaching and Gizachew observing. I observed both lessons and there were two lessons each.

<table>
<thead>
<tr>
<th>Lessons taught by</th>
<th>Observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gizachew</td>
<td>Sebsibe &amp; Amdebirhan</td>
</tr>
<tr>
<td>Sebsibe</td>
<td>Gizachew &amp; Amdebirhan</td>
</tr>
</tbody>
</table>

Table 6.3 Overview of Observers

\textsuperscript{9}The computer classroom is a computer lab room for mathematics students and teachers used to teach computer related mathematics classes.
**Gizachew’s class**

There were six groups of four students with each group formed randomly by Gizachew. He began the lesson by giving them the activity worksheets and by showing them the computer location of the applets.

![Figure 6.11 Group of students in Gizachew’s class](image)

Gizachew moved around the class giving assistance as needed.

> *When I saw Gizachew’s class, students had difficulty to understand the concept as well as language. So...remove those difficulties: when you observe the classroom you see what they were doing and then you will decide when my turn comes I will improve this ... and so it was helpful.*

Although the main aim for the observation was to give the teacher (here Gizachew) feedback on his lesson, we note here that Sebsibe learned to improve his lesson.
Figure 6.12 Gizachew’s class with other groups and Sebsibe was observing his colleagues class

*Sebsibe’s class*

Sebsibe presented his own lesson in the same classroom, and he arranged his students in groups like Gizachew did. Sebsibe’s class had eighteen students so he formed five groups with a maximum of four students in a group. After he finished organizing the groups, he gave students the activity worksheets; he also showed them the applets in the computer. During the lesson he assisted his students as needed.

Figure 6.13 Sebsibe helping one group.
Like Sebsibe, when Gizachew was observing, he came away with ideas for his own teaching.

Looking at how others really conducting classroom teaching by itself gives you something positive...or you may sometimes also comment and criticize by observing what others are doing or how other teaching. If you feel that way of teaching somehow or some respect is not comfortable, then you can learn a lesson from that presentation and you can make your own. So I can say observation is means of gathering data and way of collecting tool and is one way of learning.

![Figure 6.14 Sebsibe’s class: Sebsibe on from far left, Gizachew left center](image)

**Summary of Implementation Phase**

I noticed that my colleagues understood how student-centered instruction could be implemented. They were giving assistance and guidance to their students; they were not telling. Their students also worked independently of the teacher and discussed freely within their group during the lessons. It was obvious from their classes that both colleagues were able to shift their self-conceptions of being a teacher-centered instructor to one using student-centered instruction. Moreover they were critical observers for their colleague’s class.
6.4 Analysis of Data from Colleagues’ Research

In this section I outline the student results in the worksheet, and their responses to the questionnaire and the interview questions. This analysis shows how the lesson went and how the new way of teaching using GeoGebra by my colleagues apparently affected the students’ learning.

Here I first describe the activities that designed by Gizachew and then I analyze the students’ worksheet (Appendix D).

**The activity designed by Gizachew**

The activity in Gizachew’s lessons consisted of three parts: Activity parts I and II he used for the first day’s lesson, and part III for second day’s lesson (Appendix D). Both activities were accompanied by applets. Of the eight questions in part I Gizachew used the first three to trigger students to remember their background knowledge. So his plan was to get his students to revise their previous knowledge and which he hoped would enable them to connect to the new knowledge. On the latter point in his questions 4-8, students were to find values and determine the sign of the sine, cosine and tangent functions for special angles \(30^\circ, 60^\circ, 90^\circ \ldots 360^\circ\).

In part II Gizachew asked students to find the sign of sine, cosine and tangent functions for any angle \(\theta \leq 360^\circ\), while in part III he aimed for students to find the sign of sine, cosine and tangent functions for any angle \(\theta \geq 360^\circ\). So in this part he was challenging them a little by asking them about angles larger than 360°.

**The activity designed by Sebsibe**

Sebsibe’s lessons had two parts; Activity part I and part II, both of which parts were connected to applets he had designed. Sebsibe’s aim for part I was that it would enable students to define exponential functions by themselves. For this, in the first two questions he asked students to revise their previous knowledge. In the next four questions he asked students to come up with the definition of exponential function based on the given data and the applets. In activity part II Sebsibe asked students to determine, and to find in their group, the property of exponential function with the help of the designed activities and applets.
To support my general impressions of my colleagues’ lessons, I have chosen two exemplary answers to illustrate some of the positive results. Of course some students were not able to do so well. It has been left to my colleagues to do a careful analysis of all student worksheets collected. Their results have not been communicated to me at the time of this writing.

6.4.1 The Analysis Results from the Students’ Worksheet.

Figure 6.15 A student group worksheet in Gizachew’s lesson.

Here it can be seen that these students were able to solve the problem in the activity working together with their group. This shows that students were able to work autonomously with very little outside help. Since they had not been taught this subject matter before in this way, we can say that students in this group were able to construct their own knowledge based on the given task and with the help of the applets.
Figure 6.16 A student group worksheet in Sebsibe’s lesson. Here students were able to develop their own rule.

The above students’ worksheet result illustrates how the designed lesson enabled them to work independently, to find the rule (marked on the figure 6.11) and solve the problem by themselves.
6.4.2 Analysis of Student Responses to the Questionnaire

The questionnaires were collected from the students at the end of the second session. It should be noted that my colleagues did not require their students to write their names on their questionnaire, so many did not. Therefore much of these data are anonymous. For this reason it is not possible to provide the whole analysis of the questionnaire and compare this with data from specific groups’ worksheet. Together my colleagues collected a total of 42 individual questionnaires. I have numbered them from 1-42 in a random order. The numbers given here is reference particular students. Following are a selection of different students’ responses.

1. Did you like learning to solve sign of sine, cosine and tangent functions (exponential functions and their graphs) with GeoGebra? Please give your reason for or against.

The general results from question number 1, indicated that most students were motivated and liked learning with GeoGebra.

Yes! Because I looked graphical the result and also when the graph moves [changed] from 1st quadrant to 4th quadrant. It is [easy to] understand graphically. [student1]

Yes I like to learn [and] to solve exponential functions [because] it is easy to [understand] about exponential function from the grapy using GeoGebra. [student2]

Yes I like to learn. Because it solve and shows easily exponential functions using GeoGebra. [student3]

2. What aspects of GeoGebra applet did you like the most? List and give your reasons.

For question number 2, the results showed that most students liked the slider aspect of GeoGebra but one student disagreed with the others [student5]

The slider is the most aspect that I like … Because when I drag it immediately I seen the difference between the graphs. For example, the graph of base from 0 up to 2 when I drag the slider I seen the difference between the graphs. [student3]

The slider aspect I like it because when you drag it I seen the difference between the graph as an example. [student4]
I cannot accept it because most student do not have computer to solve their problem and because of this it is difficult …but it is very attractive. [student5]

Although student 5 could “not accept” GeoGebra because it would be unavailable to most students, s/he nevertheless admitted to finding it “attractive”.

3. Working in a group is helpful. How it is helpful? Can you explain how?

For question number 3, the results illustrated most students answer the question by referring to GeoGebra rather than group work. Some typical responses:

It has a big difference learning using GeoGebra and it is more attractive than traditional way. [student3]

I am so happy by learning using GeoGebra because it helps me to remember and to acquire new knowledge. It helps be to create and learn by myself. [student7]

In traditional teaching it is very difficult to solve the problem but in GeoGebra it is very easy. [student8]

When we learn in GeoGebra it is more clear and in traditional teaching there is no practices. In GeoGebra I practices and it is very clear so it is very important than traditional teaching. [student10]

4. Please write down your general impression of learning the signs of the Sine, Cosine and Tangent functions using GeoGebra.

For question number 4, most students were very impressed by learning using GeoGebra. Typical responses:

Sliding the graph was very impressive. [student4]

I got a lot of knowledge and I am happy now. [student7]

At this stage student responses to the questionnaire illustrate that the majority were motivated and interested by learning using student-centered instruction in a digital environment, of course these aspects cannot be separated easily in this brief analysis. We can also say that the designed lesson material had a positive effect on the students’ mathematics learning.
6.4.3 Analysis of Student Responses from Interview

My colleagues thought it would be better if I interviewed their students instead of one or both of them. The main reason for choosing me was they thought that students might be honest and truthful in the interview. It was decided that students from both classes should be interviewed together at the same time. A reason to interview them simultaneously was because the same interview questions were to be asked. The selection of students for the interview was done randomly from those who showed interest and who provided their telephone numbers on their questionnaires. Six students, three girls and three boys, were interviewed as a group. I labeled the students as S1, S2, …, S6 randomly. Here S1, S2 and S5 were female students and S3, S4 and S6 were male students. The type of interview was semi-structured and the questions were open-ended. I provide the transcript of the interview here.

1. Did you like learning mathematics with GeoGebra? Please give your reasons for or against.

   S1: Yes… I am happy by learning using GeoGebra … and I will be happy if I learn mathematics using GeoGebra in the future

   R: why? and what is your reason you like to learn mathematics using GeoGebra?

   S1: For example when I learn using GeoGebra … if I did not understand … then I can ask and discuss with my group … but when I learn by my lecturer I fear to ask … you see when I learn by my lecturers I always expect from them because of this I did not think about [it] … I said always he will teach me if I did not understand something I always expect from them … here when I learn using GeoGebra I discussed with my group and I also think about my learning … it make me active I like it …

   S2: I have also an additional idea …

   R: Ok you can add your idea

   S2: Here when I learn with GeoGebra you see how the graph is come out … it is clear and you see it how the points are connected … but when I learn by my lecturers when they draw the graph on the black board it is not clear …

   S3: I have also an additional comment
R: Ok you can give additional comments

S3: Here it simple to learn ...I like it

S4: I have a comment ...

R: You can give your comment or add your idea

S4: Here you can learn by yourself ...if you miss a class you can learn by yourself using the activity

2. What was your new experience when you learned by using GeoGebra? It is easy or difficult to learn mathematics using GeoGebra. Can you explain how it is?

S1: We used to learn from teachers...here you learn using a computer and with your group and this way of teach is new to me ...this is new experience to me and also learning by using computer is also another new experience.

S2: My new experience here you see clearly the graph in the computer ...it is not complex

S5: When we find sine and cosine value it is clear here ...you see the value ...but in our class you will use calculator and you will compute by hand and it takes long time ...here it is fast and simple to compute

S6:Here you see similar graph at the same time when they change in one plan...when they decrease you see the difference at the same time ...

S4: You see...here when you learn by this method ...I think many students start to like to learn mathematics ...when I learn exponential functions I see that the graph does not touch the x-axis ...here I understand it ...and I see it in the graph and this is new for me

3. Working in a group is helpful. How it is helpful? Can you explain how?

S1: Working in group is helpful ...because when I did not remember some concept ...then if someone in the group knows about it then you can get ideas about the concept from your group.
S3: It is helpful ....you see when we learn by our lecturers we always fear to ask our teachers ...but here in the group work you can ask your friends ...if you do not understand you can simply ask your friend ...it is good for me

S5 : Working in a group is nice ...for example when we work in a group to find the role of the exponential function last time, she (S1) found it easily the role ...then I understand it easily she showed us how to find ...so group work is good

4. Did you like the activities that were designed to use Geogebra applets? How it is helpful for you?

S3: I like both the applet and the activities ...it guides you in how to work and the applets also show you how the graph draws...

S6: The activities are so nice it gives you a general knowledge about sine, cosine and tangent function

S2: I like this activity ...if it is possible I want to learn using type of activity in the future...you will not forgot by learning using this activity but when you learn by our teacher ....they talk about the lesson then after they talk you easily forgot what he said about the lesson ...

From the interview one can easily understand my colleagues’ new way of teaching affected the students learning and motivation. Many were motivated and showed enthusiasm to learn in the future by this style of teaching.
Chapter 7 Conclusions and Discussion

7.1 Conclusions

The purpose of this research study was to explore how a specially designed professional development scenario would work in practice. Within this scenario I wanted to find out how two colleagues at the Kotebe College of Teacher Education would respond to collaborative work and joint educational research.

In this chapter, I conclude and discuss the main findings of the research study. I answer the main research and sub-research questions, and I outline limitations of the study and make recommendations for future research.

7.1.1 Research Question 1

To what extent did the professional development scenario contribute to the teacher educators’ learning of how to do educational research in their own classroom on student-centered instruction that is supported by dynamic mathematics software?

To answer the first research question I developed three sub-questions. I answer each sub-question based on my data analysis results and the teacher educators’ reflection notes.

1.1 Did observation and discussion of videos of classroom activities from others help the teacher educators to develop critical abilities regarding their own teaching?

Video and photographs of classroom activities can help educators to visualize ideas and to give them some concrete evidence about particular teaching situations. Such media make visible something that previously was only an idea. In this research, video and photograph records of others’ work were used as example (and exemplary) study materials. I explored the situation in which my colleagues and I discussed the videos and lesson materials from others. The results of the analysis of the videos and interviews show that the video observations and explorations of the teaching materials helped my colleagues to learn from others, to critique others’ work, and to reflect on and think about their own teaching. They were able to appreciate how student-centered teaching could work in a practical situation, and how dynamic geometric software activities could bring students into working in quite a different way from (their) normal or usual classroom.
You see from the video they are free ... you see that boy he move from one group to the other ... it is nice. It is so surprising...you see your students are active ...your students work independently and you see how they ... discussed [with] each other ... ho ho ho ... it is really nice way of doing ...

Observing videos and examining photographs have also given colleagues an opportunity to comment, critique, and evaluate what was done and also the different ways of teaching. From our discussions the teacher educators in this research thought that the video observations gave them a lesson about what could be done and what to consider for their own teaching in the future. We also looked at how someone else conducted classroom teaching in a similar classroom setting to ours in Ethiopia (Mainali, 2008). This by itself was a pivotal experience.

Hmm.. it is merit ...I mean it looks more like our situation...we have about 40 to 60 students in class and we do not have enough computers. We depend on working on the blackboard ...I think this is profitable for us.

I noticed that watching videos and discussing them helped the teacher educators to develop critical abilities when they later designed and practiced their own lessons. The video observations and subsequent discussions gave them an appreciation of what was for them a new way of teaching; further, because they were distanced from the scenarios shown in the videos and photographs, they were able to develop critical abilities about both the teaching lessons and the teaching materials explored (see also sub-question 1.2 below).

1.2 Did the professional development scenario encourage the teacher educators to reflect on their own practice?

It is believed that many teachers always reflect on their own practice and that they also tend to talk about it. Many think and tell others: “my lesson went well today”, “students are happy with this discussion”, and “students did not understand”. This type of reflection habit in most cases is observed by many teachers in their day-to-day practice. Most try to draw conclusions concerning what happened, but few think and ask themselves why it went so well, what the students did not understand and why not, and what was actually happening in the class. To appreciate possible answers to such questions, I think teachers should develop the habit of critically reflecting on their own practice. Critical reflection of one’s own work may not however give a teacher a complete view, but to do it with another colleague gives the person a fuller perspective. So for
more effective and probing critical reflection there must be an atmosphere of trust and reliable colleagues, I noticed that the teacher educators in this study began to reflect on their own teaching, but their reflections were initially made explicit through story telling whereas later the reflections addressed their practice in specific and concrete points. I also believe it is impossible to change one’s underlying teaching paradigm that is based on teacher-centered instruction unless one can become critically reflective about one’s practice.

The answer is yes, it is possible to construct and implement such kinds of lesson; I mean a student-centered way of teaching with very limited resources that we have. I also I remember topics in high school mathematics that I have tried with limited resources to make a little bit student-centered way of teaching...For instance I remember I tried to teach students with limited resource in Geometry class to construct using paper and to dismantle and try to understand and discover the area of prisms and solid figures.

I noticed that the atmosphere of the professional development scenario during the research period was conducive for the teacher educators to try out and use their own innovative methods, to create and construct applets, and to reflect on what they were developing.

I think if you want to ask your students this question ... I think as background knowledge we should assume the students know intuitively the definition of exponential function... if so, you can ask this question

So what do you suggest ...

One of the moments that indicated the suitability of the professional development scenario for reflection on their own work is illustrated below (quotations come from my colleagues):

Well I didn’t work on the paper you gave. I just tried other methods. Do you want to see what I did?

What I did is this ...I tried graph and it works nicely and you can change the color and things like that. This one is a rational graph.

I want to show you that it is possible to change color, thickness of the graph and so on.

The analysis of our discussions indicate that in a professional development scenario when teachers have an opportunity to explore, suggest, and contribute their own ideas, eventually the
environment enables them to reflect critically on their own work, on the other colleagues’ ideas, and on what to take into consideration in their designs regarding students’ learning. In particular for this research study of a professional development scenario, I could see that the situation was suitable for my colleagues not only to reflect but also to suggest their own ideas.

*Ok... for instance let us take the sequence of Fibonacci to create...*

*Oh no. Let’s start from the simple one like sequence which lists sequence of numbers. [R]*

*So S start with the simple one ...then we can create the element of the Fibonacci sequence...*

The other indication of the suitability of the professional development scenario was that the teacher educators developed their own applets, suggested their own topics, and worked autonomously at home. I noticed that the professional development scenario was a situation which encouraged my colleagues to reflect and also think further about their teaching. In this research I found that when a professional development scenario gives priority and encourages participants to try something new by themselves, control their own discussions, and be autonomous in their work, in the end they will not only reflect, but also suggest new ideas and new approaches. In sum, I found that the professional development scenario definitely helped teacher educators to reflect *critically* on their own practice.

1.3 *Did the incorporation of dynamic mathematics software facilitate the teacher educators to develop and practice student-centered instruction?*

The training in the professional development scenario enabled teacher educators to work by themselves with little help from me. For them it was a situation involving learning by doing. For my colleagues it was an eye opener that they could construct a GeoGebra activity which was similar to a traditional paper-and-pencil (compass-ruler) activity. As software users with some experience, they enjoyed solving problems with computer programs, but they did not yet see this could be used in a way in which students could also solve such problems for themselves. Dynamic aspects of the software make it especially useful in a classroom situation because it gives an immediate possibility to talk about mathematics and to have this new mathematics object as the point of the discussion. My colleagues found the features of the software simple and easy to learn, and serving well the purpose to develop and construct applets for supporting
student learning. In their opinion GeoGebra compared to other available mathematics software is relatively easier to use (and to learn to use) and much simpler, even to produce very good applets. Not only this, they also indicated that the software had given them motivation to take initiative and construct applets on their own.

They considered GeoGebra as a very good learning environment which they believed would give students more opportunity to develop, discover, and construct mathematical knowledge through their own efforts. In this point they also included their own applets which they had developed for students.

*When I get into it I have come across that the software is very strong and powerful. When I say powerful I mean it has a very big effect on the learning of understand mathematics concept by the students.*

In their lesson implementation I observed that my colleagues practiced student-centered instruction; they just let their students work in their groups with the software. During the classes their students were talking about and working on mathematics; the room was not silent. Beforehand, my colleagues were quite skeptical that students would actually be doing mathematics if they used GeoGebra or other dynamic geometric software in a classroom situation like this.

From results of the data analysis and the student worksheets, the indications are that GeoGebra software enabled their students to work autonomously in their groups (that is, independent of the teacher), to construct their own knowledge and to work together in a team. My colleagues acknowledged this. Based on the analysis of my observations and our discussions, I conclude that by incorporating dynamic mathematics software in their lessons the teacher educators were enabled to practice student-centered instruction.
7.1.2 Research Question 2

To what extent did teacher educators develop research ability by participating in joint educational research?

To answer the second research question I developed three sub-questions. I answer each sub-question based on the data analysis results, including the teacher educators’ reflection notes, and the interview at the end of the research intervention.

2.1 Did the teacher educators learn to engage in critical reflection about their research during the study group activities?

I involved my colleagues in their own kind of exploratory research study in which they developed lesson activities, tried them out, analyzed their data from the pilot study, and then revised the instrument material; finally they used their materials with real students as part of their course teaching. My colleagues were prepared that the pilot study might cause them to revise the instrument materials before using them in their own courses. They also wrote reflections on their learning. By reflecting on their previous and present activities in this professional development scenario, they developed ideas and skills on what to consider for their future work.

I know most ... students in my experience ... they couldn’t come up [with] a general solution for any angle \( \theta \) greater than 360°. This is what I want to ask in the second activity ... that is why I make the applets for any angle.

In their reflection notes colleagues indicated that reflection on their activities helped them to develop knowledge about what to consider when they had a similar situation. They learned that by just writing reflections on such class activities that they could realize and think about what were their strong and weak points. During the study group activities colleagues developed and learned how to reflect critically on their own work. They were very comfortable doing this.

2.2 How did the study group activities enable teacher educators to develop research ability?

I noticed that during the joint educational research period the teacher educators were collaboratively working to design and develop students’ activities and applets. They were very active and contributed their own ideas to the discussions. The professional development scenario
was supported with sample material from other researchers, videos, and dynamic mathematics applets. I found strong indication that the collaborative teamwork helped them to develop insight and also gave them opportunity to discuss how they could best describe a given idea or notion using GeoGebra.

 [...] whenever we work in a group [a] very brilliant idea will come from the group member and we discuss about the idea as a team and then we can accept and incorporate [it] as part of our team idea. I think working in team is good. You can share knowledge and different experience.

I noticed particularly that the collaborative work helped them to share ideas, develop student activities and learn from each other. The collaborative teamwork also helped them to develop skills: how to work together collaboratively, build self esteem, and become productive as a team. In turn all this supported them to learn to design student activities. To support their research in using student-centered instruction, they developed a research questionnaire and interview questions, and learned to reflect critically on their own work and that of others. The latter enabled the teacher educators to be more objective in evaluating the results of their own research efforts.

My colleagues also tested their developed lesson material with selected students by implementing a pilot study. I can say from the interview and discussion results they were able to develop research ability. This does not mean that they learned everything, but they learned and developed some useful research skills. Now for sure, they can develop their own instructional material and design their own research instruments. The e-mail I received from one of my colleagues after my return to Amsterdam illustrates this very well (emphasis is original).

Dear Amdebirhan, how are you doing there with your study and research? I am terribly sorry for not responding so fast.

I am introducing GeoGebra to my students and am using it as one tool of teaching mathematics in schools. Recently I had to give a one day training to selected mathematics teachers at Addis Ababa schools on methods of teaching mathematics. I have introduced GeoGebra to these teachers and have shown them on how the software is helping teachers teach mathematics and how students will be so active and constructive when the learn mathematics using GeoGebra. They were so fascinated by the software. The Applete that I have produced for this training purpose was about the angles subtended by the same arc or chord of a circle. I have used my
LCD projector to facilitate the training. I have attached the activities and the associated applet in case you need it. Unfortunately I couldn’t attach or somehow send the applet in its dynamic form. If there is any mechanism that I can send you the dynamic applet you can inform me. For the moment I have sent to you the static one.

Bye for the moment

Gizachew A [e-mail date: 18-07-2012]

My colleagues did not learn everything in this research project, but in general I noticed that the joint educational research attracted them to try and practice some of the educational research skills in their own classroom.

2.3 What impressions of doing classroom research were revealed in the interviews with the teacher educators?

The teacher educators were very impressed by participating and taking part in a joint educational research process. In this research study the participants indicated that they felt they were part of the research which they had not expected. I quote directly what one colleague said about his impression of being involved in this research process; his thought impresses me also.

I am part of this research work and even this research work completed as a teacher I can continue and I should be research oriented. I have GeoGebra tools and I have experience developing activities.

Such remarks do indicate that my colleagues were not only very impressed but also (and importantly) gained confidence to do research by taking part in this joint educational research process. They also thought and suggested that this way of working will improve both their professional and their school working environments.

7.2 Discussion

In this research study the professional development scenario gave the teacher educators autonomy to construct their own knowledge and suggest their own ideas, and there was ample opportunity to explore and discover on their own. The environment was designed to encourage the teacher educators to learn by doing, work in a collaborative team, take part in discussions, and develop a feeling of ownership for their contributions. Their learning was supported by
dynamic mathematics software, samples of practical study materials, videos and photographs. This environment helped them to be engaged, to be critically reflective, and to work independently.

In my opinion the collaborative work in the professional development scenario helped the participants to develop deep critical thinking skills for their learning, gave them accountability, and success in researching their own class. In addition to this the collaborative environment provided participants good use of ICT tools in an educationally appropriate context. The latter fits with the research findings of Uworwabayeho (2009) who found that collaborative action research positively changed teacher’s attitude towards the use of ICT. The collaborative environment situation enabled the teacher educators in this study to practice and research their new way of instruction. These findings are similar to those of Greeno (1998) that teachers in interactive research can work as both teacher and researcher of their own practice.

The professional development scenario in this master study gave the teacher educators opportunity to learn from others. The videos and photographs together provided a snapshot for the teacher educators to see how other instructs in a student-centered way. I noticed that when my colleagues themselves practiced student-centered teaching they were assisting and guiding their students. Their students also worked independently of their teacher and discussed freely within their group during the lessons. These points fit well with findings of Putnam and Borko (2000) who indicated that case-based teaching provides a different perception to create meaningful settings for teachers’ learning. The case-based learning was used to show practically how student-centered instruction could be implemented practically. In this research it was obvious from their classes that both colleagues were able to shift their self-conceptions from being a teacher-centered instructor to one of student-centered instructor. Moreover, they were critical observers for each others’ classes.

7.3 A New Model for Professional Development and Capacity Building

The outcomes of the professional development scenario have enabled me to suggest a new professional development model (Figure 7.1). I first explain the model; then I discuss its implications.

In this model there are four stages: the process, outcome, action and sustainability stages. Boxes in the Process Stage show the different processes I designed and carried out in this professional
development; horizontal arrows indicate the order. For example, the first box on the left represents that my colleagues’ motivations were given to me in August 2011 before I had finalized my professional development design; the second box represents the next event which was the beginning of the actual development process in January 2011; the remaining boxes indicate successive activities as shown.

The Process Stage led to the Outcomes Stage, of which the leftmost box can be further explained as depicting the safe, collegial working environment I established so that ideas could be freely shared, reflected upon, and critiqued. The middle box shows that the teacher educators developed skills and knowledge so that they could undertake future work autonomously. The final outcome in this stage is that they were able to develop and test their research instruments.

The Action Stage illustrates that implementation of the teacher educators’ student-centered lessons with a dynamic mathematics environment (GeoGebra).

The sustainability stage shows the culmination of the professional development scenario. At this point they discovered how the designed student-centered lessons worked in practice with their own students in a regular classroom. This process not only led to changes in their own perspectives as teachers but also to changes in their students’ views that there could be a different kind of mathematics classroom than the traditional which had previously been their sole experience. Concerning the latter, students found they could work together quite autonomously of the teacher. Their students also thought they could understand some aspects of mathematics better by using GeoGebra applets developed by their teacher than they had been able to in the regular traditional teaching scenario which was reliant on a teacher lecture and a textbook. Students were motivated and had started to think of mathematics as a subject with which they could work and discuss. Data from the students confirm that the teacher educators’ efforts were successful.
Figure 7.1 A Model for Professional Development and Capacity Building

Process Stage
- Ascertain motivational reasons
- Establish collegial working environment
- Show/discuss sample teaching practices as illustrations
- Encourage to develop own instructional materials
- Pilot developed materials

Outcomes Stage
- Collegial working environment
- Skills and knowledge developed
- Research instrument designed and tested

Action Stage
- Implementation and researcher’s classroom practice
- Teacher change
- Student change

Sustainability Stage
- Profound Teacher Change
7.4 Implications of the New Model for Sustainable Teacher Development

In the professional development scenario of this research project I purposefully designed and used a collegial style of training, which I consider is central to successful professional development.

One important result of this scenario was that the teacher educators became deeply involved in the professional development. Their motivating factors, both internal and external, were grounded in their willingness to participate. Certainly one motivating factor was they were my colleagues, but their willingness to try went far beyond this. For a number of reasons, it seemed to me that a collegial working environment was clearly needed. In the environment established, I thought that I should share my original responsibility (as leader). In doing this I gave the teacher educators both ownership and authority over their work. This meant that they could experience professional collegiality which in turn enabled them to work collaboratively together with each other and with me. So, although I may have started as the leader, I quickly became an equal member of a team.

A second important factor in this scenario was that the processes in which the teacher educators were engaged were supported by practical and workable sample teaching materials from others as illustration; these materials all depicted in some way a similarity to their own situation in Ethiopia. The idea of practicality has most recently been supported by Janssen, et al. (2012) and earlier reported in Guskey (1986): a “staff development program must offer teachers practical ideas that can be efficiently used to directly enhance desired learning outcomes in students”.

As my colleagues discovered when they first used their newly developed materials in their pilot studies and then, after some revision, in two of their regular classes, they also had an entirely new role compared to the one to which they had been accustomed. They were excited by the way their students could work and very interested that they themselves now understood what is meant by student-centered instruction involving dynamic mathematics software. Knowledge of (positive) student outcomes and reflection on their own practice in the new classroom environment has resulted in a profound change in the teacher educators. When students are seen to change, then teacher change becomes evident, a comparable finding to that of Guskey (1986): “A significant change in teachers’ belief and attitudes is likely to take place only after changes in student learning outcomes are evidenced.”
The teacher educators also tried their research skills and found that they had a better grasp of how to do a small research project. They realized from their research results that they have the capacity to deliver the new kind of instruction using dynamic mathematics software in student-centered instruction. In turn they have begun to encourage others to try the new methods.

The professional development scenario developed and tested in a small way in this research has to a certain extent built capacity in the teacher educators to continue the training with others. I believe that this model represents sustainability as evidenced by the capacity building which was inherent in all the activities in this professional development. Gizachew’s recent e-mail shows that he for one has taken the skills and knowledge gained in the professional development and he is now using them not only with his own students but also when training mathematics teachers in Addis Ababa. He now has the capacity to do this, and he is.

7.5 Limitations and Recommendations for Future Research

There are still some loose ends in my study. One of the limitations of my research was the short period of time in which I conducted the study, which means that I could not get results which I can be certain will endure. The teacher educators have changed profoundly, but at this point it is not known if the change will be lasting, even though they have discovered their own students’ very positive responses. The end product of research effort is a final document giving the research results, but due to the shortage of time and their other duties, the teacher educators have not as yet been able to produce their final report.

The findings in this research indicate that the professional development scenario helped the teacher educators to develop some research skills within a short period of time. Further research in this area should investigate the different factors that appeared to lead to the success of this joint education research project. Some questions might be asked in future: Is the success of this scenario due to the teacher educators’ extensive teaching experience and their thorough subject knowledge? Is their previous knowledge of (some) mathematics software a factor in their successful professionalization? How important in the success were the collegial learning environment, the teacher educators’ own intrinsic motivation, and/or the collaborative way of working? If this scenario were tried with freshly graduated (new) teachers, would the result be similar?
It is not clear if the capacity building aspect is sustainable over time. For example, what is not yet known is whether other teacher educators in other pedagogical institutes in Ethiopia will be encouraged to try the scenario and therefore test the model. At this writing I am not sure if teachers in schools once they go through similar professional development will actually use the lessons, or similar ones, in their own practice, although some at least appear to be interested in doing so. It is also not yet clear if both this scenario and the Professional Development Model are more widely applicable in Ethiopia and other countries.

My new model should be tested with other teacher educators and in other institutions before we can be sure of its applicability in other situations. I plan to continue this work.
References


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Wakwinji, I. (2010). What is it like to be quadratic? Winter Project, MMSE, AMSTEL Institute, Faculty of Science, University of Amsterdam.

### Appendix A: Research Time Table in Ethiopia

<table>
<thead>
<tr>
<th>No</th>
<th>Activities</th>
<th>Date</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GeoGebra training</td>
<td>16-20/01/2012</td>
<td>The training is based on demonstration and showing some lesson study material.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23-27/01/2012</td>
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<td></td>
<td></td>
<td>30-3/02/2012</td>
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<tr>
<td></td>
<td></td>
<td>6-10/02/2012 up to 13-17/02/2012</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Teacher educators design activities using GeoGebra</td>
<td>20-24/012/2012 through 27-29/02/2012 up to 1-2/03/2012</td>
<td>They supported by example material as reference</td>
</tr>
<tr>
<td>3</td>
<td>Pilot study on selected students on the designed activities and analysis</td>
<td>5-9/03/2012</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Updating and make ready the materials to the actual research study.</td>
<td>12-17/03/2012</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Implementation period</td>
<td>17-26/03/2012</td>
<td>Researching period</td>
</tr>
<tr>
<td>6</td>
<td>Data collecting</td>
<td>16/01/2012 up to 26/03/2012</td>
<td>Research data collection time: throughout the research study period</td>
</tr>
<tr>
<td>7</td>
<td>Meeting with Mary &amp; André</td>
<td>02/04/2012</td>
<td>Amsterdam, UvA</td>
</tr>
</tbody>
</table>
Appendix B: Training Material Used in Professional Development Scenario

Training of teacher educators’ introduction of GeoGebra and
study of GeoGebra based instructional materials

By
Amdeberhan Ayeligne Tessema

January 5, 2012
<table>
<thead>
<tr>
<th>No.</th>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to GeoGebra</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Study GeoGebra based of instructional material from Amdebirhan winter project lesson...</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Study GeoGebra based of instructional material from Inambao winter project lesson……</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Study GeoGebra based of instructional material from Bhesh Master research lesson……</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Articles for reading</td>
<td>6</td>
</tr>
</tbody>
</table>
1. Introduction to GeoGebra

In this introduction lessons I and the joint researchers’ team will construct applets using GeoGebra on some selected topics of mathematics. The training will be conducted through demonstration. It requires a direct participation of the teacher educators. I will give them GeoGebra materials as reference if they need to refer some command. The reference materials are selected in order to help them to construct their own lessons. The selected materials are focused on constructing of geometric figures, manipulating and analysis algebraic expression through input command.

The suggested topics for discussion are:

1. Constructing line segment, circle, perpendicular line, parallel lines and right angle triangle from the given line segments and right angle.
2. Constructing equilateral triangle and regular hexagon.
3. Reflection, rotation transformation of figures through a point and a line.
4. Drawing and finding the roots of any polynomials. Finding maximum, minimum and in general property of the given polynomial function.
5. Sequence of numbers, listing of numbers, listing of coordinate points
6. Construction midpoint of line segment or in general partition of line segment into equal points.
7. Trigonometry equation, sine function, cosine function and their graphs.
8. Integral, upper sum and lower sum.
9. I will let them suggest topics.

All of the above topics will be discussed together with the teacher educators. The participants will actively participate on the discussion. In the discussion period I will let them to discuss, to figure out, to try out and to come up solution.

Some of the discussion questions after finishing the training are:

1. What do you think about using GeoGebra to construct applet?
2. What is your impression so far of this ICT tool?
3. What did you think this type of construction using GeoGebra?
2. Lesson study from Amdebirhan winter project lesson
In this lesson study the participants and I look at the activities and discuss how it is designed and developed. We will discuss them by bringing questions like, how it is designed. How it is helpful for the student to understand the topics? They may suggest their own idea or comment or impression to the activities. Then after this I will show them parts of video how the lesson was implemented for students in Dutch classroom. They may suggest their own impression on the teacher activities, the students’ activities during the lesson when the watch the video. Discussion question may be raised during and after watching the video. We will also discuss how student-centered way of teaching conducted. We may discuss about student-centered way of teaching. We may discuss questions like, how it is differ from the normal way of teaching.
Some of the discussions questions like:

1) What does student-centered teaching mean to you?
2) It easy to construct student-centered lessons? Are there other possible resources that allow us to construct student-centered method of teaching other than ICT?
3) It is possible to create this kind of mathematics lessons to students in Addis Ababa school? Do you see how the students working in groups? What will helps for working in group? What do see as the role of teachers? of students?
4) What are your impressions of the students’ activities in this study?
5) What did you observe from the video? What is your observation and understand when students working in groups? Is it possible to research the students understanding or draw some conclusion about the change in students understanding, motivation and attitude?

3. Lesson study from Inambao winter project lesson
In this lesson study we will discuss as the previous one but discussion is more on the similarity and difference between the two lessons.
Some of the discussions questions are:

1) What is your impression on the two lessons?
2) What did you observe from this lessons?
3) How did you see the teachers and the students’ work on the two lessons? Did you see some similarity or difference from the above lesson? What is that, let us discuss
4. Lesson Study from Bhesh master research

This lesson has some difference from the above one. In this lesson the teacher presented his lesson with limited resources. So, we will discuss how it is possible to design student-centered method of teaching with limited resources. I hope this lesson will show them the real sense of student-centered methods of teaching.

Some of the discussions questions are:

1) Is possible to construct and implement students-centered methods of teaching with limited resource and with a large number of students?
2) How this is possible in Addis Ababa school situation?
3) Is it possible to practices this type of lesson in our institution?

5. Selected Articles for reading

The following articles are selected to give some idea about researching and designing activity using ICT tools for teacher educators.

2) Learning to Develop Mathematics Lessons with GeoGebra (http://www.mathstore.ac.uk/headocs/9224_haciomeroglu_e_etal_geogebramathlessons.pdf)
Appendix C: Final Interview Questions for Teacher Educators

The semi-structured interview questions are as follows:

1. What did you learn by reflecting on your class activities?
2. What is your general impression of the introduction to GeoGebra? What was your general reflection when you are trained to use GeoGebra for designing applets? What is new for you?
3. What was your first day experience with GeoGebra when compared to your today’s skills or knowledge with GeoGebra? Are you comfortable to use GeoGebra to design any mathematics idea or concept now? Can you explain how?
4. Do you think GeoGebra make it easy to design student-centered activities?
5. Do you think designing learning activities easy, difficult and what is over all experience when you design your own learning activities? Is it first time to design activities or you have some experience. If you have some experience what was the difference or similarity?
6. Are you now comfortable to use GeoGebra for designing activities for your future mathematics class?
7. Do you think that working as a team helps you to do research on your classroom? To what extent? What do you think the benefit and disadvantage of working as a team to do educational research?
8. Do you think the classroom observations are helpful to do research?
9. Do you believe whether designing such activities and researching what happens in the class helps you to get the better view or maybe we can do such approach on our teaching?
10. What do you think was find the most difficult thing to do in this research or what do think was easier to conduct? What suggestion would you have to this kind of joint research or even further joint research?
11. Did you find difficulty to analysis data? Difficult, easy or durable?
12. Do you remember what were you thought about our research project before we did it and what were your expectations? How do you think differently about it and do you have now some experience? What are these experience.
13. What did you find difficult in this joint research? What did you miss or would you like know about mathematics education research?
Appendix D: Student Activity Sheet Designed by Gizachew

Kotebe College of Teacher Education first year mathematics student’s activity

Group name: _______________________________

Activity I

Instruction I: Use GeoGebra Applet Ia and answer the following questions

1. What is the value of \( \sin \theta \), \( \cos \theta \) and \( \tan \theta \)? come up to a solution for each question in group.

   \[ \sin \theta = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \cos \theta = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \tan \theta = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

Instruction II: Move the slider in GeoGebra applet Ib to the require angles and answer the following questions

2. What are the values of

   \[ \sin 30^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 60^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 90^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 120^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 150^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 180^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 210^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 240^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 270^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 300^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 330^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]

   \[ \sin 360^0 = \_ \_ \_ \_ \_ \_ \_ \_ \_ \]
3. From the above values of sine function can you group the values in which the sine function has the same sign? Write the quadrants in which the sine values are positive? Write the quadrants in which the sine values are negative? please discuss in group.

4. What are the values of

\[
\begin{align*}
\cos 30^\circ &= ____ \\
\cos 60^\circ &= ____ \\
\cos 90^\circ &= ____ \\
\cos 120^\circ &= ____ \\
\cos 150^\circ &= ____ \\
\cos 180^\circ &= ____ \\
\cos 210^\circ &= ____ \\
\cos 240^\circ &= ____ \\
\cos 270^\circ &= ____ \\
\cos 300^\circ &= ____ \\
\cos 330^\circ &= ____ \\
\cos 360^\circ &= ____
\end{align*}
\]

5. From the above values of cosine function can you group the values in which the cosine function has the same sign? Write the quadrants in which the cosine values are positive? Write the quadrants in which the cosine values are negative? please discuss in group.

6. What are the values of

\[
\begin{align*}
\tan 30^\circ &= ____ \\
\tan 60^\circ &= ____ \\
\tan 90^\circ &= ____ \\
\tan 120^\circ &= ____ \\
\tan 150^\circ &= ____ \\
\tan 180^\circ &= ____ \\
\tan 210^\circ &= ____ \\
\tan 240^\circ &= ____ \\
\tan 270^\circ &= ____ \\
\tan 300^\circ &= ____ \\
\tan 330^\circ &= ____ \\
\tan 360^\circ &= ____
\end{align*}
\]
7. From the above values of tangent function can you group the values in which the tangent function has the same sign? Write the quadrants in which the tangent values are positive? Write the quadrants in which the tangent values are negative? please discuss in group.

8. Fill the following table by labeling the sign of sine, cosine and tangent in each angle (use + for positive sign & - for negative sign)

<table>
<thead>
<tr>
<th></th>
<th>0°</th>
<th>30°</th>
<th>60°</th>
<th>90°</th>
<th>120°</th>
<th>150°</th>
<th>180°</th>
<th>210°</th>
<th>240°</th>
<th>270°</th>
<th>300°</th>
<th>330°</th>
<th>360°</th>
</tr>
</thead>
<tbody>
<tr>
<td>sinθ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cosθ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tanθ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity II

Move the slider in GeoGebra appletII to any angle in each quadrant and answer the following questions:

1. Is the $x$ co-ordinate positive or negative in Q1? How about the $y$ co-ordinate?

2. What is the sign of $\sin \theta$, $\cos \theta$ and $\tan \theta$ in Q1? [Positive or negative]

3. Move the slider so that $\theta$ is a second quadrant angle. If $\theta$ is a second quadrant angle, then what is the sign of the $x$ co-ordinate? The $y$ co-ordinate?

4. What is the sign of $\sin \theta$, $\cos \theta$ and $\tan \theta$ in Q2?

5. Move the slider so that $\theta$ is a third quadrant angle. If $\theta$ is a third quadrant angle, then what is the sign of the $x$ co-ordinate? The $y$ co-ordinate?

6. What is the sign of $\sin \theta$, $\cos \theta$ and $\tan \theta$ in Q3?
7. Move the slider so that $\theta$ is a **fourth quadrant** angle. If $\theta$ is a fourth quadrant angle, then what is the sign of the $x$ co-ordinate? The $y$ co-ordinate?

8. What is the sign of $\sin \theta$, $\cos \theta$ and $\tan \theta$ in Q4?

9. Complete the following table by deciding whether the three functions are positive or negative in each of the four quadrants:

<table>
<thead>
<tr>
<th>$\theta$ is an angle in quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>$\sin \theta$</td>
</tr>
<tr>
<td>$\cos \theta$</td>
</tr>
<tr>
<td>$\tan \theta$</td>
</tr>
</tbody>
</table>
Activity III

You may use GeoGebra applet III to answer the following questions

10. What is the sign of \( \sin \theta \) for \( \theta = 360^0, 390^0, 420^0, 450^0 \ldots \)?

Write down the possible value of \( \sin \theta \) on which the sign of \( \sin \theta \) is positive for \( \theta \in [0, \pi] \).

Can you list on which quadrant the sign of \( \sin \theta \) is positive? or negative?

Please come up a solution with your group. (try to write a general formula for your solutions).

11. What is the sign of \( \cos \theta \) for \( \theta = 360^0, 390^0, 420^0, 450^0 \ldots \)?

Write down the possible value of \( \cos \theta \) on which the sign of \( \cos \theta \) is positive for \( \theta \in [0, \pi] \).

Can you list on which quadrant the sign of \( \cos \theta \) is positive? or negative?

Please come up a solution with your group. (try to write a general formula for your solutions).

12. What is the sign of \( \tan \theta \) for \( \theta = 360^0, 390^0, 420^0, 450^0 \ldots \)?

Write down the possible value of \( \tan \theta \) on which the sign of \( \tan \theta \) is positive for \( \theta \in [0, \pi] \).

Can you list on which quadrant the sign of \( \tan \theta \) is positive? or negative?

Please come up a solution with your group. (try to write a general formula for your solutions).
Appendix E: Student Activity Sheet Designed by Sebsibe

Kotebe College of Teacher Education first year mathematics student’s activity

Group name: _______________________________

Activity I

Using the following activity sheet and the GeoGebra applet 1 and come up a solution to the problem with your team.

1. Use the following table and GeoGebra Appl 1 to answer question a, b, c, and d.

<table>
<thead>
<tr>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(n)</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

a. What is the value of $A(4)$, $A(5)$ & $A(6)$

b. What is the rule for $A(n)$?

c. What is the value $A(n)$, when $n=10$?

d. Can you draw the graph of $A(n)$ from the value you have found and compare with the graph from GeoGebra applet 1 by selecting the checks box? Do you find similarity or difference with your work? Please discuss with your group and come up to a solution.
2. Use the following table and GeoGebra App 1 to answer question a, b, c, and d.

<table>
<thead>
<tr>
<th>K</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>B(k)</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

a. What is the value of B(4), B(5) & B(6)

b. What is the rule for B(k)?

c. What is the value B(k), when k=10?

d. Can you draw the graph of B(k) from the value you have found and compare with the graph from GeoGebra applet 1 by dragging the slider and selecting the checks box? Do you find similarity or difference with your work? Please discuss with your group and come up to a solution.
3. Open GeoGebra applet 1 and compare your answers of question 1 & 2 with the graph by sliding the slider bar.

4. Drag the slider bar labeled by $a$, what do you recognize from the result? Please discuss and write your answer with your group.

5. Drag the slider bar labeled by $b$, What do you recognize from the result? Please discuss and write your answer with your group.

6. Have you encounter such type functions before? Can you name them?
Activity II

Use the following activity sheet and GeoGebra applet 2 and come up to a solution to the following questions.

1. Drag the slider from 0 to 2. When you drag the slider a what do you notice? Can you discuss with your group about this phenomenon. Please write your observation when you drag the slider and explain your observation to your team.

2. When you drag the slider a from 0 to 0.5 what type of graph do you get? Can you name this graph? What is the difference or the similarly with the graph you obtain in activity 1?

3. When you drag the slider at the point a=0 what type of graph do you obtain? Can you give the reason why it touches the x-axis? Please discuss with the group why the reason is?

4. When you drag the slider at the point a=1 what type of graph do you obtain? Can you give the reason why it intersects only the y-axis? Please discuss with the group why the reason is?

5. When you drag the slider from 1 to 2 what type of graph do you obtain? Can you give name this graph? When you compare the graph you obtain in activity 1 what did you observe? Is there any similarity or difference? Please explain and write your reason. Please discuss with your group why the reason?

6. Compare the graph you obtain when you drag the slider from 0 to 0.5 with the graph you obtain when you drag from 1 to 2. What difference and similarity did you observe? Can you explain why this happen?
Appendix F: Post Lesson Interview Transcriptions

1. Gizachew’s

1. R: What did you learn by reflecting on your activities?

G: when we .....or usually when I reflect I try to list/jot down or write things that I have learnt or surprised me. To summarized what I learnt by just writing dawn reflection on such class activities is that when I write down my reflection once again I realized and think what where my strong point or weak points and it helps me to think what were my strong or weak points. Write reflection by itself it will help you to think about your work or activities that you learnt from your previous experience.

2 R: What is your general impression of the introduction to GeoGebra?

G: You mean general impression that I have about the software
R: yes...ya, your impression about the software
G: That is that is really ... first of all for me it is just new software and I have never heard about GeoGebra I didn’t know before this software. When I get into it I have come across that the software is very strong and powerful. When I say powerful I mean it has a very big effect on the learning of understand mathematics concept by the students. It is relatively very easy and simply to learn, to understand and to develop applets but it is feat is immense and beyond my expression.

R: An extension of the above questions. What was your general reflection when you are trained to use GeoGebra for designing applets? What is new for you? Can you explain?
G: To tell you frankly actually I had a little bit worry because I might not be able to understand the technicality of the software to preparing applets of activities
but when I get into after getting the training I found GeoGebra is relatively easier simpler even to produce very good and strong applets with the software.

R: what is new for you?

G: Everything was new for me starting from the software itself, designing students activities. I personally didn’t know that …. I was think designing first applets and then designing students activities but finally I realized that activities must first developed and then applets construction based on the concept of the activities this things were new for me.

3. R: What was your first day experience with GeoGebra when compared to your today’s skills or knowledge with GeoGebras?

G: I remember in our first day training of GeoGebra I was trying to construct basic things almost manually I can say. I was using the software but I was doing things almost the usually pen and pencil way for instance to draw and construct using pen and pencil manually but later I have seen that this things is done automatically by the software by clicking icon on the software. As discovered later everything done by the software itself when I click a circle the circle drawn but in my first day experience I was trying to do this thing manually but it is not.

R: So…Are you comfortable to use GeoGebra to design any mathematics idea or concept now? Can you explain how?

G: you mean now I think yes

R: How? Can you explain?

G: yes with little bit reservation …I have learnt a lot of thing in the training time. I tried to develop applets during in our training time with you and I have also tried to develop more applets by my own initiative because the software has initiated me and it has given me a lot motivation to try out to construct applets for mathematics concept by my own. I have tried to develop my own applets like how to proof Pythagorean Theorem, how students might learn the Thales Theorem and
the like and also I am trying constructing other applets now. I can say I am more or less comfortable now still I have limitation to construct sophisticated mathematical applets I have seen in the internet sophisticated applets that are constructed by people and I wonder how they constructed this applets and I wish I could also developed such sophisticated applets. Probably their might be certain syntax that I should know or learn to construct such type of sophisticated applets I think for my school mathematics I am now comfortable to construct applets.

4.

R: Do you think GeoGebra make it easy to design student-centered activities?

G: Oh hundred percent yes

R: Can you explain? How?

G: First of all the software is really there to produced applets which will give the student more chance to learn by their own if the applets designed in such way. so the teacher we have practically seen this in the class we have tested in our class and for instance my role was guide and help students by moving and I can say the software can help to construct students –centered way of teaching.

5.

R: Do you think designing learning activities easy, difficult and what is over all experience when you design your own learning activities?

G: I can say it is not easy because I have tried to correct my activities when I was designed my activities in sign of sine, cosines. I have amended the activities a lot of times. You may designed activities sometimes this activities may not arrange from simple to complex to meet the intended or the expected outcome, or the activities may not gives students the sufficient information that are need to the student to come up to certain generalization to the intended knowledge or the activities may not be sequentially arranged or the activities may not sometimes give attention to the background knowledge of students and understanding all this things and developing activities, correcting this things it need knowledge and skills. It is not like simply writing mathematical formula and definition I think it
require knowledge and skills. From my experience designing activities is not easy but when you accustomed with it you may develop good activities.

R: Is it the first time to design activities or you have some experience. If you have some experience what was the difference or similarity?

G: In this way yes and it is my first time experience. I developed lesson activities for my usual way of teaching meaning without using technology. Some times in my usual way of teaching I used designed activities to the student to come up or generalized some mathematics concept but this way of design activities it is my first time.

R: If you have some experience developing activities previously, so what was the difference and similarities designing activities based on GeoGebra with your experience?

G: well I mean that we develop using GeoGebra applets I see the activities and the applets should go hand in hand but when you construct activities in traditional ways you may not use a certain figures or visual object in accompany with the activities. I think this is the difference developing with and without GeoGebra.

6. R: Are you now comfortable to use GeoGebra for designing activities for your future mathematics class?

G: I think yes, with very much enthusiasm and motivation. I have started that

R: How?

G: I am started that I am now constructing some activities from different mathematics lesson and it show that how much I motivated I think. For sure I will continue to use it because it will save my time and I think it is also give very sold knowledge for the students.

7. R: Do you think that working as a team helps you to do research on your classroom?

G: yes is my answer. Working in team really helps much clearly we are different and every individual experniece and knowledge is different and whenever we work in a group very brillight idea will come from the group member and we discussed about the idea as a team and then we can assept and incoprate as part of our
team idea. I think working in team is good you can share knowledge and different experience.

R: To what extent it is good or helpful?

G: what do you mean when you say to what extent? In what sense you are expecting me to answer this?

R: I mean and my question is to what extent the team work helps you or good for you?

G: As long as the team is committed for that purpose and the team size is manageable it is more advantages than working individually because you can share knowledge and experience.

R: What do you think the benefit and disadvantage of working as a team to do educational research?

G: Team work sometimes more advantages and also it is disadvantages if the size may not be manageable, variation in time devotion, the team member may not continue, variation interest among the team member will make it disadvantages and if it is manageable in size and the team member are committed working in a team is good for me.

8. R: Do you think the classroom observations are helpful to do research?

G: my answer is yes because observation of other class weather real class or class that recorded in video I think it is a means of learning or one tool of gathering information about what you have to do in the future. Looking at how others really conducting classroom teaching by itself gives you something positive or you may sometimes also comment and critics by observing what others are doing or how other teaching and if you feel that way of teaching somehow or some respect is not comfortable then you can learn lesson from that presentation and you can make your own. So I can say observation is means of gathering data and way of collecting tool and is one way of learning. Yes it is useful I can learn by observe live class or a class recorded in video.
9. **R:** Do you believe whether designing such activities and researching what happens in the class helps you to get the better view or maybe we can do such approach on our teaching?

**G:** Ya…. When you design such activities and when you start analysis what happen after the class in the class is help you this gives you a lot of thing for you what you have to do in the future. The type of activities that you are going to design for future lessons will be done in such a way that you have taken real inputs from the activities that you are constructed and practiced aerial?? therefore if I have designed certain activity and I have tested it then all this things will give me relevant feedback and input as to how to develop the future activities .I think it is relevant I mean designing such activities, researching it helpful for future teaching.

10. **R:** What do you think was find the most difficult thing to do in this research or what do think was easier to conduct?

**G:** First of full I want to tell you frankly designing the activities with GeoGebra was very challenge for me and the other problem was the scheduling of the research program, arranging time table for meeting was a challenge that I have found in the joint research.

**R:** What suggestion would you have to improve or to overcome problem for this kind of joint research or even for further joint research?

**G:** I mean suggestion in what way

**R:** For instance improving or addressing this problem you list out, what is your suggestion to improve or to solve?

**G:** when it is a team work or in joint research, first things those stakeholder who participated in that team must be devoted to the whole work and they must be 100 % interested and there must have the same understand to the whole work if this happen then we can overcome scheduling problem or other problem and if there is a problem everybody will share the problem.
11. **R:** Did you find difficulty to analysis data?

**G:** Ya …well… I have teaching experience not research experience that has negatively affecting me to associate me the research question with the data that I have at hand and so relating the data and the research question and try to interpreting keeping in mind the research question was a little bit difficult for me.

**R:** So it is difficult, easy or durable for you to analysis your data?

**G:** Analyzing data is not simple it need research experience but finally I think I have tried to managed it hahaha…

12. **R:** Do you remember what you’re thought about our research project before we did it and what were your expectations?

**G:** Actually at the begging I expected you are doing your research and I thought you need some information from me as like other researcher those who come and asked me to fill there research question after that I didn’t meet them before but in this research I am part of the research this I didn’t expect I am part of the research.

**R:** How do you think differently about it now and do you have now some experience? What are these experiences?

**G:** You mean what?

**R:** I mean now you had some expectation but after involving in this research your expectation change and you were part of the research.

**G:** you mean now that is right … now my mind is already changed because I am part of this research work and even this research work completed as a teacher I can continue and I should be research oriented I have GeoGebra tool and I have experience developing activities.

**R:** can you tell me your experience or research skills you have got by involving in this join research
G: One experience that I got is developing activity and it is a big thing for me and the other thing which is new and important thing is developing applets, the other thing is a team work skill and conducting research in team, gathering data using varies tools all such things are good and additional knowledge to me that I acquired being part of this research.

13. R: What did you find difficult in this joint research?

G: what I found difficult in the research was I tried to mentioned above difficulty working in team, difficulty of producing good GG applets, developing activities and I think I able to manage it for our research. Producing good activities and applets were difficult to me at first time and now I have some knowledge.

R: What did you miss or would you like know about mathematics education research?

G: Actually I have a teaching experience but I have a very limited experience in mathematics education research and I read article in the internet about mathematics education research has shown a lot of progress and development and from
2. Sebsibe’s

1. R: What did you learn by reflecting on your class activities?
S: Well you see...as a teacher I do not have this skill previously. I just reflect on word not written so it is new for me now and by reflecting on my first time training it help me to remember and to know my weak and strong point... I think it helpful ...

2. R: What is your general impression of the introduction to GeoGebra?
S: Well, when I first saw software my questions was what is the difference about this software it is any better than calculating and do graph or another thing...? Another things was can a person learn the software quickly? Because that was important for me for two reason. For one thing students might get bored or even they might quite very quickly due to the lack of understanding of the software not the subject that is one thing I was afraid of when I first saw the software. The second one was I thought that students will be forced to do two things for one things they might forced to concentrate on their subject that is what we want them to do. The second thing they might be straggling to know software instead of concentrate on their own subject on they are study they might be very troubled by lack of knowledge of the software and in the process of knowing the software they might spent considerable time in which they could used the time for study their subject. But I was along on both accounts for one thing the learning curve is not that step you can learnt easily and the second thing the software is more than calculator software and more than graphic software. Here they can set and think and try to do different kinds of learning activity to achieve understanding of the subject. So it was not that boiled and I found it to be easy software to use. Using this software students can easily to understand mathematics concept I think.

R: Last time you asked me if you remember about the use and importance of software...
S: I changed my mind now ....but when I saw the first time these two questions was bothering me and last time I remember I asked you the two questions... I understand now.
R. Ok..i have an extension of the above questions. What was your general reflection when you are trained to use GeoGebra for designing applets? What is new for you? Can you explain?

S: My impression is that any teacher can use it to design applets for his/her subject.

R: If he trained by ...

S: ya ya ...the important things it requires training, some kind of manual is necessary. Because the help file of the software it is not that much helpful on the computer. Moreover, when you want to use it say for example for solid geometry, higher integrals and soon...

R: you mean for advanced mathematics

S: ya... you feel that it lack some things. But for secondary, elementary school and for two year college level like our institution it is very good software. I wish there is some kind of materials for self learning.

R. I think there is some material in the internet for self learning... I hope you will find some

S: ok

3. R: What was your first day experience with GeoGebra when compared to your today’s skills or knowledge with GeoGebra?

S: well on the first day training if I recall correctly ... we saw how to draw perpendicular line, parallel line ..segment like that. I was impressed because if I used ruler, compass try to do those things from my experience students find difficult to do and for teacher it will took two or more periods but here we can construct within few minutes you can construct. So I was impressed. The more I study the software you can do more sophisticated things like animation .... Which are very helpful for teaching learning process. So I think there is improvement I have see from my first day.

R: So...now are you comfortable to use GeoGebra to design any mathematics idea or concept now? Can you explain how?

S: I am that confident... I am not sure if I can do it when I try it now that is different matter. I am hoping to do very different things or to construct applets for what I will be teaching of course expect one thing ... this syntax or script of the
software things. I haven’t see that ... I do not if there is material I will search for that ... I see the help file of the software is not that much helpful.

R: there is online material
S: ok I will find online material ..

4. R: Do you think GeoGebra make it easy to design student-centered activities?
S: Well it makes it easy of course
R: How?
S: Now the job of the instructor will have to change. In the case of the lecture method he picks a book that is the standard text book for the course and then take some note from it and then the instructor will lecturing class that is it. But here the paradigm is changed. The most important part of teaching learning process here is not what happens as far as the instructor concerned it is how much he has designed the lesson or how much preparation put in to it and once very good activity designed then the job of the instructor almost more than halve job done. Just coaching job it will be for he/his.
R: So you are saying it is easy for constructing student-centered way of teaching using GeoGebra
S: Ya it is easy ...no question except that he has to put some effort in it.

5 R: Do you think designing learning activities easy, difficult and what is overall experience when you design your own learning activities?
S: It is easy and not easy. How is it easy because the software is easy to use and provided that you can set and think and work you can prepare very good applets. It is not easy because I have been lecturing for the last I do no more than twenty years and change from that and preparing a material which give freedom to the students and instead being me the center of the things I think it is very difficult. In other word changing myself is difficult that is what I mean.I think that is difficult
R: Is it the first time to design activities or you have some experience. If you have some experience what was the difference or similarity?
S: Yes!! it is my first time that is my problem. What I was doing I prepare my lecture by reading different books and text book and then I go to the board and give them lecture and write out note ... that is it.
6. **R:** Are you now comfortable to use GeoGebra for designing activities for your future mathematics class?

**S:** Ya, not for all courses. There are some advanced courses I am not sure how much I can use the software for those subjects. But for my first and second year classes and ...may be ...I do no how much I can use it for number theory ...but for this class I think I can use it. For this class I can design very good lessons using the software... that is what I feel

7. **R:** Do you think that working as a team helps you to do research on your classroom?

**S:** Ya! It is helpful for getting insight and also you might discussed on how you will best describe a given idea or notion using GeoGebra. So it is very helpful. Team work is necessary ...in fact even design the courses will be easier if our instructor here can form a team or two and work together.

**R:** To what extent it is good or helpful?

**S:** Well working as a team is helpful as I said because there will be sharing of past experience , sharing of new ideas so that is very good and it is important ...where lies the problem of teams there might be conflict of interest this may be one difficulty that can arise. I do no.... as far as I am concerned I haven’t formed any team in preparing my lecture and so on .but here we worked as team and so we did shared many ideas on constructing the applets... so I do not see any problem being forming team and working through them provided that there is a good leaders in a team and every one welling to work hard except that I think I do not see any problem. I found it good in these activities we have done because we shared different ideas.

8. **R:** Do you think the classroom observations are helpful to do research?

**S:** Yes it is helpful. Why was it is helpful I could see were students have difficulty in. When I saw G class students have difficulty to understand the concept as well as langue. So it is good to easily remove those difficulty when you observe the
classroom you see what they were doing and then you will decide when my turn comes I will improve this ...this things and so it was helpful. I think it must practiced a lot...this is what I feel.

9. R: Do you believe whether designing such activities and researching what happens in the class helps you to get the better view or maybe we can do such approach on our teaching?

S: Better view of what?

R: I mean better view of your teaching, better view of your subject teaching or your way of doing ...your teaching and better view of what your student learning... by designing such activities and researching what happens in your class...

S: Ya .. ya..

R: how?

S: It helps me ...for one thing in try to communicating with the students in preparing the subject... I know the subject but the questions is how do you present it for the students and how can we use the software to learn the subjects ... ok so you feel the difficulty of students learning how do they think but when you lecture you do not care what they feel how student think about the concept just deliver what you brought and go out. We were argued among ourselves this one is a better approach and that one is not the better approach but this one has this problem it might hinder their understanding....we were arguing among ourselves before we use the activities in class. So the most important thing for me .. I mean.. there might be other use...the most important thing for me is I start how the students understand and perceive the very problem itself...so...is very important ... it makes you think a lot about the subject not only the subject and it makes you to think how going to deliver the subject. That is a very good improvement for me.

10. R: What do you think was find the most difficult thing to do in this research or what do think was easier to conduct?
S: The most difficult … I think the construction of activities is difficult … but not that much. The most difficult part in this regards were for deciding at the initial step was the difficulty part or the initial stage to construct activities is really difficult for me… it takes me long time to decide how to do it and that was also the most interesting part as well.

11. R: Did you find difficulty to analysis data?

S: Data on what?

R: For instance data from observation, from questionnaire and student worksheet

S: ya .. it is difficult not because of the difficulty of the activities but our students are poor in langue and they do not experience very well I think this was the difficulty. In my class we were there and I think from their worksheet I see students work very well and from my observation from G class I see the students were doing fine.

12. R: Do you remember what you’re thought about our research project before we did it and what were your expectations?

S: well my expectation was you would have stayed in here for some weeks in my class and I thought you are going to come to my class may see and take my class that is why I sent you the college curriculum. So that you may see and then you prepare your activities and you may apply your activities in my class but it was not like that we work together and I found in the contrary.

13. R: What did you find difficult in this joint research?

S: Well …. I do not see any difficulty there but for a person lecturing for so many year this is a different thing as I have said. If it could be possible there is training for programming like for writing script for the software. In my view the software is good as far as concerned teaching.
S: You asked me what did you miss or would you like to know mathematics education research.

R: Ya you can answer

S: Hmm…. I haven’t done any kind of research on that area so I do not know what you expect but the aim of such research must be to improve the teaching and learning processes so in that case we have been advocated in the college try…to the instructor move from traditional method of teaching to student-centered method of teaching I am afraid the college did not succeed to achieve this objective if there is some additional training such like this may improve or help to achieve the college objective