ABSTRACT

YURTSEVEN AVCI, ZEYNEP. Online Tools in an Authentic Mathematics Curriculum and the Impacts on High School Students' Attitudes and Learning: A Case Study. (Under the direction of Drs. Ellen Vasu and Kevin Oliver.)

The purpose of this revelatory case study is to investigate the integration process of the online communication and collaboration tools into high school students' mathematics education and their impact on student attitudes and learning within an authentic curriculum. This study was completed with four high school classes with two teachers. The data for this multiple case study was collected through classroom observations, student and teacher interviews, document analysis, teacher reflections, and an attitude questionnaire administered to students. The findings of this study suggest that using online technologies for communication and collaboration purposes might have potential to enhance student learning and influence the development of positive attitudes. Although, quantitative impacts in this study were mixed; the majority of the students demonstrated positive attitudes towards using online tools for problem solving and had positive perceptions about the impacts of using online tools on their learning.

The research questions were: How do student-student interactions, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum? How does interaction, communication, and collaboration via online tools impact on student learning of an authentic mathematics curriculum? In what ways are students' emotional, behavioral, and cognitive attitudes affected by using online tools with an authentic mathematics curriculum at the high school level? Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

Online Tools in an Authentic Mathematics Curriculum and the Impacts on High School Students' Attitudes and Learning: A Case Study

by

Zeynep Yurtseven Avci

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Curriculum and Instruction

Raleigh, North Carolina
2012

APPROVED BY:

Dr. Ellen S. Vasu
Co-chair of Advisory Committee

Dr. Kevin Oliver
Co-chair of Advisory Committee

Dr. Karen Keene

Dr. Lori Holcomb McClaren

Dr. Bonnie C. Fusarelli

DEDICATION

To my beloved husband, Huseyin Avci, my grandparents, and my parents.

BIOGRAPHY

Zeynep Yurtseven Avci was born in Ankara Turkey. She has completed her early education in Turkey. She graduated from Ankara University, Mathematics Department, in 2002. She completed Master of Science in Ankara University Graduate School of Natural and Applied Science, and Master of education in Gazi University Institute of Educational Sciences in 2005. She taught Mathematics to students from different grade levels for three years in Turkey. She is currently a graduate student in Instructional Technology Program at North Carolina State University.

"*Knowledge is to understand*

To understand who you are.

If you know not who you are

What's the use of learning?"

Yunus Emre

(Edited by Peter Y. Chou)

ACKNOWLEDGEMENTS

The author would like to express her most sincere appreciation to her advisors, Prof. Ellen S. Vasu, and her co-advisor Prof. Kevin Oliver for all their support, encouragement and many hours for greater in depth discussion to provide their valuable suggestions on her study and research. The author also would like to express her deep indebtedness to Prof. Karen Keene who have supported, encouraged, and believed in her through this journey. The author also expresses her sincere thanks to her thesis committee members, Prof. Lori Holcomb McClaren and Prof. Bonnie C. Fusarelli for their insightful advice, and encouragement throughout her Ph.D. program.

Huge thanks go out from the author to Prof. Karen Keene and Prof. Robert E. Young who provided the author the unique opportunity to be a part of MINDSET project; and Krista Holstein and Richelle C. R. Dietz for their patience and spending hours with the author for the Voice Thread recordings.

The author would like to express her thankfulness to the teachers and students who participated in this study. They provided generously of their time and their insights during the implementation, interviews and other data collection processes.

The author is grateful to Republic of Turkey Ministry of National Education for supporting her English educational course in Boston, MA and their financial support during her Ph.D. education at NC State University.

The author is also thankful to all her professors in NC State University and her teachers from elementary to higher education.

The author would like to express her deepest gratitude to her husband, Huseyin Avci; her parents, Zehra and Hikmet Yurtseven; husband’s parents, Hanim and Huseyin Avci; her siblings Hatice, Ahmet, and Zuhal and all extended family, relatives, and friends for their endless love, constant support, care, and prayers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Background

Technology in Mathematics Education

The use of computer tools in mathematics education has been discussed and studied for over forty years (Kaput & Thomson, 1994), but discussions on its effectiveness and types of applications still continue to develop. Taylor (1981) suggested three ways of using technology in teaching and learning: as a tutor in which the computer environment provides instruction on a specific content; as a tutee where the student takes a role in the programming of a computer activity; or as a tool where software helps students to perform complex or time-consuming tasks. Even if Taylor's theory provided a strong framework for theorizing the role of computers in teaching and learning mathematics in 1980's; technology has been changing rapidly. With emerging technologies there are a lot of new possibilities for using technology for educational purposes that were not available in prior years. Taylor's theory does not define specific ways in which individuals' or groups of learners' can use technology; since they were not available in 1980's. Further, Willis and Kissane (1989) defined the role of technology as a *catalyst* in which computers are used for provoking mathematical explorations and discussion or promoting problem-solving skills. This approach recognizes the potential of technology for interaction among students, although it does not cover all the increasingly creative and sophisticated ways to use technology in mathematics education. Willis and Kissane's approach was extended by Goos and Cretchley in 2004, who view the computer in mathematics education as a tool for visualization, higher order thinking, and collaboration.

Online Technologies in Mathematics Education

Bruns and Humphreys (2005) argued that computer use in education must be much more than basic content delivery. Alternative teaching and learning practices are needed that are more project-based and more collaborative in nature. They suggested Wikis, MOOs, Web-fora, and blogs are among the applications that can be used to ensure more interactive and creative learning environments. In these platforms, students enact their understanding, and create and communicate their knowledge. Duffy and Bruns (2006) suggested that wikis, blogs, and RSS feeds were among the socially mobile learning environments that allowed collaborative content creation, peer assessment, formative evaluation of student work, and individual and group reflection on learning experiences. Himpsl (2007) determined (as cited in Krebs, Ludwig, & Muller, 2010) some of the possible classroom uses of wikis as: an online platform to collect information and relevant links for a specific learning objective, a recording tool for brainstorming sessions, and as a method to prepare Wiki-based Web-Quests.

Hoyles, Kalas, Trouche, Hivon, Noss, and Wilensky (2010) point out that a limited number of studies have been conducted on the integration of web-based technology into the teaching and learning of mathematics with the purpose of enhancing student learning by communicating and collaborating online. Their studies varied in terms of mathematical concepts, for example: (1) to explore and discover fractions and fractional relations (grade level is not specified), (2) using Texas Instruments (TI) graphing calculators for algebra, (3) the convergence of infinite sequences and the properties of infinite decimals, and (4) solving mathematical problems. The grade levels also varied from elementary to high school. Another example is Beatty and Moss' (2006) study that utilized Knowledge Forum (KF, database software), to provide 4th grade students with a platform for mathematical discourse. KF was used after students had participated in a 12-lesson instructional sequence of early algebra. The purpose of the study was to investigate the impact of collaborative problem-solving on the development of students' mathematical skills. Students were allowed to give only text-based entries into the system. Results show that working on a student-managed database supported students' deepening conceptual understanding by providing them access to each other's theories and perspectives on the problems posed. Students also strengthened their justifying skills by participating in discussions, questioning each other's theories, and comparing ideas in the community of practice they developed.

A number of other studies that were conducted using online technologies have also indicated that electronic communication is a promising way to improve student learning and helped to develop positive attitudes (Nguyen, Yi-Chuan, & Allen, 2006; Garcia & Romero, 2009; Krebs & Ludwig, 2009; Krebs, Schmidt, Henninger, Ludwig, & Muller, 2010). Nguyen, Yi-Chuan and Allen completed their study with middle school students using homework problems adopted from the Connected Mathematics series (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998). Studies by Krebs & Ludwig (2009) and by Krebs et al.

(2010) were completed in higher education for project-based math learning. Students were given a task to use for conceptualizing and elaborating their own math projects beyond the regular lectures. In Garcia and Romero's study two ninth, one tenth, and one eleventh grade class with 79 students in total participated. The focus of the study was emphasized as being *mathematical literacy*, which is defined as the students' abilities to pose, formulate, and solve mathematical problems while analyzing, reasoning, and communicating their ideas effectively.

Computer Supported Collaborative Learning (CSCL)

Using online technologies for communication is becoming more popular among today's students. The increasing popularity of the use of online platforms in children's daily lives raises the question of how new technologies can be used to expand communication and collaboration for learning and educational purposes. Today, CSCL is an emerging field of research that focuses on how technology can facilitate the sharing and creation of knowledge and expertise through peer interaction and group learning processes (Resta & Laferriere, 2007).

Laborde and Stra¨ßer (2009) argue that the use and development of appropriate tools have a huge influence on mathematical learning. Teaching methods should be supplemented by new tools to help students to advance in mathematics. Computer-supported collaborative learning is dealing with how computers can be used to support student learning through communication and collaboration.

Resta and Laferriere (2007) argue that the development of learning sciences and the needs of the knowledge society require environments that are challenging in terms of problem-solving and knowledge-building and have more time and space flexibility. This study should add to the growing body of literature investigating online technology use and student learning through communication and collaboration in mathematics education at the high school level. It will address the important issue of how students' attitudes and learning of an authentic curriculum, which employ multi-step mathematical problem-solving tools to solve and interpret real life situations, will be affected by use of online communication and collaboration tools.

Biggs' (1989) 3Ps generic model: (a) presage variables; like demographics about the instructor, the curriculum, the learning environment, and learner characteristics; (b) process variables; like, interventions, interactions, type of student participation, and use of distance learning; and (c) product variables; like quality of learning outcome; will be used as a framework to collect data for this study. Resta and Laferrière (2007) suggest Biggs' model as a framework to assess the added value of technology used to support collaborative learning.

Problem Statement

How do online tools layered on an authentic mathematics curriculum at the high school level affect student attitudes and learning?

The International Commission on Mathematical Instruction (ICMI) devoted its 17th ICMI study (2010) to various technology uses in mathematics instruction, especially in secondary and tertiary mathematics. The study addresses the timely subjects of mathematics and technology, while offering a comprehensive synthesis of work in the past twenty years of internationally diverse studies. Under the section named *Connectivity and Virtual Networks*, Celia Hoyles - who was awarded the first Freudenthal medal by ICMI in 2004 for her work on technology in mathematics teaching - presented the growing emergence of new opportunities and possibilities as virtual technologies are more fully integrated into mathematics education:

> Digital technologies are already changing the ways we think about interacting with mathematical objects, especially in terms of dynamic visualizations and multiple connections that can be made between different kinds of symbolic representation. At the same time, we are seeing rapid developments in the ways that it is possible for students to share resources and ideas and to collaborate through technological devices both in the same physical space and at a distance… ICMI Study 17 was keen to explore the potential and challenges for mathematics education of these new levels of connectivity… It was envisaged that there would be considerable impact on teaching and learning in the short, medium, and long term. (Hoyles et al., 2010, p. 439)

While it was acknowledged that there is a growing potential for positive change by using online technologies in teaching and learning mathematics, Hoyles revealed that little research had been completed at the time about the impact of connectivity on mathematics teaching and learning.

Resta and Laferriere (2007) posited common learning benefits of computer-supported collaboration as: academic achievement, development of higher order thinking skills, student satisfaction (e.g. attitudes to subject domain), individual and group products, and group cognition (individual contributions and their linkages). However, the divergent structure of CSCL literature in terms of learning context, knowledge domain, the complexity and duration of the learning tasks, the type and size of the groups, and the number of participants prevents making comparisons and in-depth analysis. Resta and Laferrière (2007) and Gress, Fior, Hadwin, and Winne (2010) point out the need for evidence-based research in the developing field of CSCL that provides in depth descriptions of the participants, contextual elements, and analysis methods "to better understand presage variables such as student characteristics and technology affordances that enhance or constrain collaborative learning" (Resta and Laferrière, p. 77). This study is an evidence-based study for in the field of mathematics among the various areas of CSCL.

This study was completed with four high school classes and with two teachers. Each teacher had two classes. One of their classes was assigned as the Online- Tools class that was introduced and had access to VoiceThreads and Google Documents, and the other class was assigned as the No- Tool class that was not introduced any online technologies. Classroom observations were made to collect sufficient information about the characteristics of the students, the learning context, and the teaching methods that teachers apply. Detailed information about the affordances of the tools chosen for this study, VoiceThread and Google Docs, are provided later in this document. Through the analyses of student communication and collaboration using online tools and analyses of student attitudes and learning, this study aimed to contribute to the theoretical as well as the empirical understanding and development of CSCL research in mathematics education at the high school level.

Dillenbourg, Järvelä, and Fischer (2009) argue that the affective and motivational aspects of computer-supported collaboration have been neglected in past studies. The affective issues are determined as one of the dimensions of attitude. Therefore, the attitude analysis in this study should contribute to CSCL literature in terms of outcome variables, and also provide information about affect issues in CSCL. Resta and Laferrière (2007) emphasize the need for research about other outcome variables of CSCL such as achievement and the development of higher order thinking skills. Through the analysis of student work in Google Documents for the homework and group projects, this study should contribute to the literature for the outcome variables in CSCL such as academic achievement and establishing group cognition.

Gress et al. (2010) argue that there is a plethora of self-report and a paucity of baseline information about the above collaboration and collaborative activities in CSCL research. For the attitude component of this study, both qualitative and quantitative data were collected to make more accurate conclusions. Baseline information about the participants such as: (a) technology experiences, (b) attitudes towards mathematics and (c) attitudes toward the use of technology in learning mathematics were collected thorough individual student interviews at the beginning of the study. The analyses of text-based student work in Google Documents provide the opportunity for deeper understanding of collaborative activities.

Purpose of the Study

The purpose of this study is to investigate the integration of online communication and collaboration tools, namely VoiceThread and Google Documents, into high school students' mathematics education and its impact on student attitudes towards mathematics and technology and learning of an authentic curriculum. This integration of online tools with face-to-face instruction aims to extend students' classroom experience with the asynchronous availability of Web 2.0 technologies, while providing them with the ability to create work on the Internet that could be shared with others in an effort to develop the 21st-century skills that students need.

Research Questions:

1. How do student-student interaction, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum?
2. How do interaction, communication, and collaboration via online tools impact student learning of an authentic mathematics curriculum?
3. In what ways are students' emotional, behavioral, and cognitive attitudes affected by using online tools with an authentic mathematics curriculum at the high school level?
4. Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

Definition of Terms

Authentic Curriculum

Authentic learning suggests more connections with real-life experiences in the educational settings, and ranges from experimentation to real-world problem solving (Lombardi, 2007). It aims to expand students' learning experiences to make connections outside of the classroom, while providing them more application of the rigorous knowledge they gain in their school experience from the real-life. In addition, according to McKenzie, Morgan, Cochrane, Watson, and Roberts (2002) an additional outcome of authentic learning is a constructivist curriculum in which "learning that triggers critical self-reflection, through which students' worldviews and values are confirmed or challenged" (abstract, p. 426). They argue that: authentic learning "is a measure of a curriculum's relevance or appropriateness to the world that graduating students will enter" (p. 426).

The curriculum, **M**athematics **IN**struction using **D**ecision **S**cience and **E**ngineering **T**ools (MINDSET), that was chosen for this study consists of contextual problems from business as well as from students' lives that employ multi-step mathematical problem-solving tools to solve and interpret real life situations, which makes it an authentic curriculum. In particular, the MINDSET curriculum nicely aligns with both the Discrete Math and the Advanced Functions and Modeling (AFM) curricula; which are the curriculums for the high school grades (9-12) for the state of North Carolina (US). AFM provides students an in-depth study of modeling and applying functions. Home, work, recreation, consumer issues, public policy, and scientific investigations are just a few of the areas from which applications should originate. Discrete Mathematics includes: Introduction to the mathematics of networks, social choice, and decision making. These two curricula encourage modeling and problem-solving as does the MINDSET curriculum. According to North Carolina Standard Course of Study appropriate technology, from manipulative to calculators and application software should be used regularly for instruction and assessment for both curricula.

Communication.

LittleJohn and Foss (2008) state that *communication* is a central element of human life that is really important and complex. So, there are several definitions of communication that focus on different aspects of communication among scholars. In the study that conducted by Frank Dance in 1970, he examined the definitions of communication that arise from diverse fields and publications. He did a content analysis to capture the main themes among these different definitions. His findings will be explained to provide the bigger picture of various aspect of defining communication. He came up with thirty different terms which are derived from fifteen conceptual components. These components included: symbols/verbal/speech, understanding, and interaction/relationship/social process, reduction of uncertainty, process, transfer/transmission/interchange, linking/binding, commonality, channel/carrier/means/route, replicating memories, discriminative response, stimuli, intentional, time/situation, and power.

Instead of explaining this study from those various aspects, three points that were suggested as points of conceptual split of those fifteen different components by Dance will be the focus for this study: "(1) the level of observation, (2) the presence or absence of intent on the part of the sender, and (3) the normative judgment of the act.

In this study: (1) the main focus is on the students, so one of the aspects of communication was student-student communication as human beings, in terms of the level of observation. At the same time the online tools as a system that was used by students and teachers to communicate were analyzed, (2) both intentional and unintentional types of communications were included, and (3) some of the communications were successful, accurate, and effective; while others were not.

Collaboration.

Lipponen (2002) defines the term *collaboration* as: "any activities that a pair of individuals or a group of people performs together" in a general sense (p. 2). However he argues that there are different definitions of collaboration among researchers, but all emphasize "co-construction of knowledge and mutual engagement of participants" (p. 2). For example, Rochelle (1992) focuses on the construction of shared meaning in collaboration. He argues that collaboration shares a lot of features with everyday informal interaction. In this sense, Lipponen claims that some researchers consider collaboration as a special type of interaction, while others embrace a broader definition of collaboration, like "a process of participating in knowledge communities" (p. 2). In this study, collaboration was analyzed both as a participation process in group work and as co-construction of knowledge.

Interaction.

Similar to *communication* and *collaboration*, the term *interaction* has been interpreted and defined in different ways by scholars. For instance, Anderson (2008) suggests *interaction* as a multi-functional term in educational settings. According to Sims (1999), the learner can play a proactive role in computer-mediated learning environments with enhanced participation in learning process; which imply richer communication and meaningful learning with more interactive form of learning.

Anderson (2003) stated that the term interaction is traditionally used to refer to classroom-based dialogue between students and teachers; but is expanded to include synchronous and asynchronous dialogue at a distance, and also getting responses and feedback from inanimate objects and devices in time. Sims (1999) defines the term *interactivity* as: “the facilities provided by a computer based application to provide the user with both control of the process and communication with content. This communication involves both the user initiating an action and the computer responding to that action”. In a broader sense Wagner (1994) defines interaction as: “reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another” (p. 8)

Anderson (2008) included student-student, student-content, student-teacher, teacher-content, teacher-teacher, content-content interactions as common components of an online learning model. That model developed by Anderson will be used as a framework to analyze different types of interaction occurred during this study.

Web 2.0

O'Reilly (2007) defines Web 2.0 as: "a set of principles and practices that tie together a veritable solar system of sites that demonstrate some or all of those principles, at a varying distance from that core" (p. 19) and provides some of the core competencies of Web 2.0 companies as:

- ✓ Services, not packaged software, with cost-effective scalability
- ✓ Control over unique, hard-to-recreate data sources that get richer as more people use them
- ✓ Trusting users as co-developers
- ✓ Harnessing collective intelligence
- ✓ Software above the level of a single device

Conceptual Framework

The argument of using online communication and collaboration technologies in face-to-face mathematics instruction to enhance student learning and attitudes in this study has two main conceptual frameworks: the first conceptual framework is Vygotsky's social constructivist theory and the second conceptual framework is the blended form of learning. Both theories will be explained in detail below:

Conceptual Framework #1: Social Learning Theory

In social constructivist theory, Vygotsky (1978) suggests a "socially constructed mind" that arises from the culture in which it was constructed. Vygotsky's (1962, 1978) social constructivist theory emphasizes the importance of culture, the role of language, and the zone of proximal development as the crucial factors in learning. The inclusion of culture recognizes the influence of culture and the symbols within the culture on higher order thinking skills and problem-solving skills. The culture, symbols, and language used in the culture influence the interaction which takes place among peers and with teachers in both traditional and technology-rich classes. The role of language includes two forms of language: social language, which is the communication with others; and inner speech, the self-talk of the learner, which is important while monitoring the metacognition of learners. The zone of proximal development refers to the point at which a learner has partly mastered a skill, and the point at which the learner can learn more effectively with the assistance of a more skilled adult or peer.

Vygotsky’s social constructivist theory was chosen as one of the conceptual frameworks of this study because of its recognition and emphasis on the social structure of learning. Immersing online communication and collaboration tools into face-to-face instruction in this study suggests a different type of culture and language than solely face-to-face instruction. Student participation in the solution process of a problem through online tools in this study requires students to use a social language to make statements and solve mathematical problems. This new culture coming into student face-to-face instruction also offers different types of assistance from their peers and teacher, since they are communicating not only face-to-face now. There is a communication platform that is available also outside of the class period.

Conceptual Framework #2: Blended Learning

Blended learning generally is defined as the mode of instruction that combines face-to-face and virtual methods and tools (Bonk & Graham, 2006; Pape, 2010). It has been increasingly implemented in several learning settings (So & Bonk, 2010; Pape, 2010). So and Bonk (2010) suggest applying the blended mode of instruction in Computer Supported Collaborative Learning (CSCL) environments "to bring the continuality of learning experiences across multiple time and space to create more holistic and integrated learning experiences" (p. 190).

Osguthorpe and Graham (2003) and Bonk and Graham (2006) argue there are different types and levels of mixing online and face-to-face instruction in blended mode. They determine three basic types as: activity level blending, course-level blending, and program-level blending. The first two are more pedagogical, while the third one is more administrative. In this study, providing students with platforms to communicate and collaborate with each other outside of the class was more course-level blending, since it combined distinct face-to-face and computer mediated activities as a part of the course (Bonk and Graham, 2006). In this blended form that was applied in this study, students did not only receive the information; but they also constructed knowledge through their dynamic interactions with the help of online tools. This form of blended learning is defined as a *transforming blend* by Bonk and Graham, 2006 as well (p. 13).

So and Bonk (2010) posited that a lot of CSCL contexts are already using a blended mode of instruction, rather than being completely online or face-to-face (So & Bonk, 2010).

Pape (2010) argued that the use of online tools to communicate, collaborate, and publish in blended mode is extending the school day or year while developing the 21st-century skills students need. Blended learning provides opportunities for the learner which are offered by new technologies, while at the same time it continues to offer the critical discourse features of face-to-face instruction (So, 2009). Hence students have a variety of ways to demonstrate their knowledge.

Significance of the Study

Current technologies are opening new windows in our lives every second with new opportunities that were not possible before. However, those technologies require different skills in the workplace for a new generation (Smith, 2004). Tapscott (2009) names those born between 1977 through1997 as the *Net Generation*. He argues that: "the Net Generation was different from any other generation, because they were the first to grow up surrounded by digital media" (p. 2) and the Internet is the first place they communicate, understand, learn, find, and do many things. Alternative teaching and learning platforms are needed that are more collaborative in nature that will enact student understanding by giving them opportunities to create and communicate their knowledge. These platforms will also change the nature of the formative evaluation of student work, as well as both individual and group reflections of students on their learning experiences.

Smith (2004) pointed out that there is a decrease in the number of young people who continue to study mathematics past the age of 16. He determined that possible factors for the decrease were the perceived poor quality of teaching and learning, as well as the failure of the curriculum to excite students. In this regard, this study aims to increase the quality of teaching and learning so that students are more engaged due to the authentic nature of the curriculum and the use of current technology-based collaboration tools. Moreover, as Smith (2004) has stated, the demand for graduates and postgraduates in strongly mathematically oriented subjects has grown significantly over the past decade. Negative student attitudes toward mathematics are an important factor preventing them from studying mathematically oriented subjects in higher education. Townsend and Wilton (2003) report a negative and resistant-to-change attitude toward mathematics among higher education students that reflects low self-efficacy. According to Galbraith and Haines (1998) higher education students have negative attitudes toward mathematics because of their negative experiences with mathematics in their secondary education. In this regard, it is important to provide students with opportunities where they can develop positive attitudes toward mathematics in their secondary education which should eventually lead to positive attitudes toward mathematics-based fields in their higher education.

Recognizing (a) the rapid change in technology and its impact on the new generation in terms of learning and communicating, (b) the need to provide students with platforms in which they can experience current communication and collaboration technologies, and (c) acknowledging the presence of negative attitudes among students in higher education, I hypothesize that: Using online communication and collaboration technologies (namely VoiceThread and Google Document for this study) in their high school mathematics experience can help students to learn mathematics better and to improve their attitudes towards mathematics and learning technologies.

Collecting detailed data through multiple data sources about presage, process, and product variables is intended to provide adequate information to readers for future investigation of collaborative technologies. The findings of this study would also be helpful for researchers who are interested in the particular affordances of the two online tools used in this study, VoiceThread and Google Documents, for computer-supported collaboration. Since the scope of the CSCL applications is broad, it is important to understand the particular structure of different learning settings and learners from different levels. The findings of this study would identify some important factors about using online tools in mathematics education on a high school level for collaboration purposes.

Overview of the Study

This study is a multiple-case study with both quantitative and qualitative data. It was completed with four high school classes and two teachers during the spring 2011 semester. Each teacher had two classes. One of their classes was assigned as the Online- Tools class that was introduced and had access to VoiceThreads and Google Documents, and the other class was assigned as the No- Tool class that was not introduced any online technologies. The data for this multiple case study were collected through classroom observations, student and teacher interviews, document analysis, teacher reflections, and an attitude questionnaire administered to students. The qualitative data were analyzed by open coding to capture all of the emerging themes. Creswell and Plano-Clark (2007) suggest one application of mixed methodology is the triangulation design where the purpose is to collect different but complementary data on the same issue. In this sense, quantitative data for the attitude component of this study will be used to triangulate the qualitative findings.

In this chapter the overview of the study has been explained including the purpose, the key terms, and the conceptual framework of the study. In chapter two, a review of the literature on important aspects of this study is presented. In chapter three, the detailed information about the study design, data collection, and analysis strategies are covered. In chapter four, the finding for each research question are presented. In chapter five the findings in chapter four are expanded, the researcher’s reflection on the current theoretical literature as well as the suggested directions for future research by the researcher are presented.

CHAPTER 2: LITERATURE REVIEW

The focus of this study was: using online tools in high school mathematics education for communication and collaboration; and investigating the impacts of using those tools on student learning and attitudes. Each component of the focus of this study has a long history in its own right. Since the focus of the study is multidimensional, the general background information about each main dimension will be provided in this section.

Tools have been used in mathematics education for a long time, for various purposes. The first section of the literature review will provide the background information about technology use in different settings and for different purposes in mathematics education. Computer use for collaboration is not a new idea. CSCL is an area of research in which the collaborative use of computers is the focus. The second section of the literature review is a review of different studies from various fields that have been studied under the CSCL umbrella. The third section includes studies about collaborative technology use in mathematics education. Student attitudes also have been studied in various settings in mathematics education. The fourth section includes general background for attitude studies in mathematics education and covers some exemplar studies that investigated the effects of different technologies on student attitudes. The last section explains the conceptual and theoretical frameworks of this study.

Background of Technology Use in Math Education

The use of computer tools in mathematics education has been discussed and studied over forty years (Kaput & Thomson, 1994), but discussions about its effectiveness and the various types of applications still continue. At first it was proposed that giving students access to the broad range of technologies available would enhance the learning experience, raising motivation, engagement, and understanding. Over time researchers and educators determined that access is not the only issue to using technology effectively in classroom. Several other issues have been raised relating to the content, the type of technology, the purpose of technology use, and so on.

Kaput and Thompson (1994) analyzed the first 25 years of technology use in mathematics education under three main categories: (1) For the first more superficial studies computers or calculators were used as supplemental tools in existing curriculum and instruction; like Behr and Wheeler (1981), Creswell and Vaughn (1979), Gaslin (1975); or for the delivery of existing content, like Fuson and Brinko (1985), Hativa (1988), Henderson, Landesman, and Kachuck (1985), Keats and Hansen (1972); (2) A second level of studies examined more developed and complex issues in terms of learning and cognition, such as “how it can be used to support problem-solving” (Kaput & Thompson, 1994, p. 676), like Blume and Schoen (1988), Heid (1988), and Kraus (1982); and (3) The third level of studies were more focused on students’ conceptualizations instead of comparisons, like Clements and Battista (1990), Edwards (1991), Hatfield and Kieren (1972), Noss (1987), Olive (1991), Szetela (1979), and Thompson (1992). The first wave did not report a lot of information about technology's impact on student attitude or performance (Kaput & Thompson, 1994, p. 676). Even if the second level studies were deeper than the first level; their foci were mostly the process, and they did not provide a lot of information about the impacts of use of technology. While the third level studies were leading new perspectives and opening new discussions, they still did not answer questions such as what are the impacts of technologies on student performance.

Since the 1990s, researchers have been investigating technology use in classes more deeply. Two main foci of these studies have been which technologies are used and what the impact of those technologies is on learning. In the report of the Princeton Educational Testing Service 1998, the relationships between various types of educational technologies used in schools and students' mathematical achievement were examined. Learning games, drill and practice, content applications, and simulations were among the most reported technologies used by students. The results indicated a significant positive relationship between uses of educational technology and students' mathematics achievement for eighth graders, while positive uses were not too high for the fourth graders. Similarly, Catley (2003) and Isiksal and Askar (2005) reported marked improvement in student achievement in mathematical concepts when they used *Autograph*, which is a "dynamic British software operating in graphs, coordinates, bi-variate data and single-variable statistics and probability" (Isiksal & Askar, p. 340). In Deaney et al.'s (2003) examination of technology uses in different subject areas, mathematics was the most cited domain in which students used technology in their learning activities, implying there is a tendency to use technological tools in their mathematics classes among students when needed access and opportunities are given and they are encouraged to use them. Function graphing and using SMILE software were reported specifically for mathematical content. The Internet is being used mostly for inquiry purposes, while spreadsheets and calculators are used for analyzing and graphing data.

While most of the studies focused on using technology to help students comprehend the content mathematically, in time more studies were conducted on technology use in mathematics classes for other purposes. For years, curriculum and software developers have continued to search for new strategies and ways to create better computer environments to "promote understanding, child-centered learning, and connections among experiences and areas of knowledge" (Clement & Sarama, 2005, p.59). While some research highlights the possible enhancement opportunities by using emerging technologies in classes (Deaney et. al., 2003; Hennessy, Ruthven, & Brindley, 2005; Pierce, Stacey, & Barkatsas, 2007), others (Artigue, 2002; Guin & Trouche, 1999) argue that learning with those tools can be superficial with only mastering the skills to use that specific technology instead of mastering the content. According to Artigue (2007), we are in a new era in terms of technology use in mathematics education. She named some commonly used technologies such as computer algebra system (CAS), spreadsheet, dynamic geometry software, and graphic calculators as the first constructs of technology use in mathematics education, and argues that now we have entered another phase in which online and tutorial resources are available (Artigue, 2007). Peressini and Knuth (2005) presented five leading ways of current technology use in mathematics classrooms for educational purposes as: management tool, communication tool, evaluation tool, motivational tool, and cognitive tool.

Computer Supported Collaborative Learning (CSCL)

Studies on using technology to support collaboration began in the 1960s with Doug Engelbart's work on asynchronous collaboration support for teams distributed geographically (Lipponen, Hakkarainen, & Paavola, 2004). The literature indicates that there is not a specific time that CSCL emerged as a separate field of study, but that it was inspired by Computer-Supported Cooperative Work (CSCW) (Lipponen, 2002; Lipponen, Hakkarainen, & Paavola, 2004). CSCW research focused on how collective managing and sharing of knowledge within virtual teams and organizations can be supported by groupware (Galegher, Kraut, & Egido, 1990; Greenberg, 1991; Grudin, 1994). The term groupware refers to the information technology that provides the higher level of coordination and cooperation needed to support individuals working together in organizations.

Koschmann (2002) defines CSCL as: "… a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts" (p. 20).

Dillenbourg, Järvelä, and Fischer (2009) analyzed the last two decades of CSCL research divided into three ages: (1990-1995) - Engineering social interactions by careful design of CSCL environments, (1995-2005)-Growing a scientific community, and (since 2005)- Integrating collaborative activities within physical, virtual and mobile spaces and teacher orchestration. This can be used as a framework to analyze CSCL studies over time, but there are no clear-cut ends and beginnings as mentioned by Dillenbourg et al. (2009). Thus it can be more appropriate to analyze what has been studied as the focus in the context of computer-supported collaboration.

The diverse history of CSCL research includes various learning tasks and concepts (Lipponen, 2002; Resta & Laferrière, 2007) in several content areas such as learning sciences, computer science, human computer interaction, instructional psychology, and educational technology (Baker & Mayer, 1999; Lehtinen, 2003; Hadwin, Winne, & Nespit, 2005). The focus of those various studies include: collaborative knowledge building (Scardamalia, Bereiter, & Lamon, 1994; Lipponen, 2000; Weinberger & Fischer, 2006; Beatty & Moss, 2006); student reasoning and levels of argumentation (Hoadley & Linn, 2000); the concept of participation (Guzdial & Turns, 2000; Lipponen, Rahikainen, Hakkarainen, & Palonen, 2002); student cognitive and metacognitive understanding (Brown, Ellery, & Campione, 1998; Chalmers, 2009); emotional and motivational aspects (Järvenoja & Järvelä, 2005), student satisfaction (Ocker & Yaverbaum, 1999); group cognition (Stahl, 2006), self-regulation, emerging, and scripted roles (Fisher et al., 2007; Strijbos & Weinberger, 2010); and orchestration (Dillenbourg et al., 2009).

This study focuses on four major concepts from the literature about computer supported collaboration because of their essential role in CSCL literature and their importance for understanding this study. *Cooperation and collaboration* and *knowledge construction and group cognition* are included in this section, since they are among the key concepts to understand CSCL literature and where this study fits in the literature. Another concept called *Blended Learning and CSCL* is included; because the instruction for this study with online tools will be in blended form, so it is important to understand how blended learning relates to the CSCL literature. The section called *scripting in CSCL* is included. Since some scripts were used in this study, it will be useful to learn about how scripting was explained in the literature.

Cooperation and Collaboration.

Lipponen (2002) posited that while the first “C” in CSCL stands for computer, there have been different interpretations for the second “C”. For example; it may refer to collective in Pea (1996); or to coordinated, cooperative, or collaborative in Koschmann (1994) (as cited in Lipponen, 2002). Although Lipponen (2002) argues that there also have been different interpretations for the meaning of the whole acronym, the focus of CSCL is given as: “how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members” (p. 72). In this regard, it is not so important what the second “C” stands for, but it is important what is being studied as a means of cooperation or collaboration.

Resta and Laferrière (2007) and Kirschner, Martens, and Strijbos (2004) highlight the cooperative or collaborative meaning of the “C” word. Although they both argue that there is not a consensus among researchers about the definition of cooperation and collaboration, or their commonalities and differences, both emphasize the commonalities given below:

- Learning is an active process.

- The teacher has a facilitator role.
- Teaching and learning are shared experiences between teacher and students.
- Students participate in small group activities.
- Students take responsibility for their learning.
- Students reflect and articulate on each others' assumptions and thought processes.
- Students develop social and team skills.

CSCL research covers a broad range of studies including: "two students working for 30 minutes in a rich synchronous environment" and "a community of several thousand members who interact asynchronously on-line over several years to develop a piece of software or an encyclopedia" (Dillenbourg, Järvelä, & Fischer, 2009, p. 3). Dillenbourg, Järvelä, and Fischer (2009) argue that collaboration among peers is directly or indirectly shaped by the CSCL environment, and can be designed. Although learning collaboratively introduced better results (Johnson & Johnson, 1999), those results firmly relate to how productive the group interactions are.

Scripting in CSCL.

"Scripting" in CSCL is not the same as "scripting" that is referred to in programming. In the context of CSCL, scripting refers to specifying roles such as typist, discussion leader, and secretary; or in identifying activities and activity sequences in CSCL studies. Even if collaborative learning is assumed to enhance learning processes and outcomes, establishing effective knowledge building collaboratively is a challenge for students in a computer-supported collaborative learning (CSCL) environment (Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, and Fischer (2009). Strijbos and Weinberger (2010) present the role concept as a promising construct for analyzing and facilitating CSCL. Two basic approaches were determined in terms of roles in CSCL: “the *emerging roles* perspective that focuses on the roles that participants develop spontaneously in support of their collaborative learning activities,” and the “*scripted roles* perspective that focuses on how the collaborative learning process can be facilitated by structuring and prescribing roles and activities to the learners” (Strijbos & Weinberger, 2010, p. 491).

Weinberger, Stegmann, and Fischer (2010) determined another way of scripting as facilitating argument construction, instead of distributing activities and orchestrating social interactions, to guide learners engaging in specific activities in a specific sequence. According to Weinberger et al. (2009), scripts scaffold collaborative learning processes and support learners with the activity types and sequence. Villasclaras-Fernández, Hernández-Leo, Asensio-Pérez, Dimitriadis (2009) add *assessment* as another essential component in CSCL scripts. The authors argue that assessment is among the most essential components of any learning scenario so it must be included in CSCL scripts. This way of scripting was used in study by providing students (a) the instructions for the collaborative activities to facilitate argumentation; and (b) the teacher rubric to guide and engage students in specific activities. Scripts were provided in the Google Documents for each homework or project. The details about the scripts that were used in this study are explained in materials and tools section in chapter 3.

Knowledge Construction and Group Cognition.

Knowledge construction has been defined as the main purpose of collaboration in CSCL. Innovative uses of computer technology make it possible to share thoughts by people who are separated spatially or temporally through local and global networks (Lipponen, 2002; Stahl, 2006). "Brainstorming and critiquing of ideas can be conducted in many-to-many interactions, without being confined by a sequential order imposed by the inherent limitations of face-to-face meetings and classrooms." (Stahl, 2006, p. 1) Computer support can help to enhance the limits of individual cognition. It offers different forms of conducting small groups and helps to manage the complexity of the collaboration. The group cognition, which will be developed by small group interactions, exceeds what each group member could achieve individually (Stahl, 2006, p.2).

Collaborative knowledge building diverges from online learning in which networks are used for distribution of knowledge and communication between one teacher and geographically distributed learners (Stahl, 2006). In a collaborative knowledge building environment, the teacher is more a facilitator than the distributor of the knowledge. Students not only socialize and exchange their ideas and personal reactions; instead they develop some kind of knowledge artifact that requires high-level cognitive activities. "In effective collaborative knowledge building, the group must engage in thinking together about a problem clarification, a textual solution proposal, or a more developed theoretical inscription that integrates their different perspectives on the topic and represents a shared group result that they have negotiated" (Stahl, 2006, p. 3).

The text-based interactions through computer-supported collaboration are defined as a new mode of interaction from oral to literate by Stahl (2006). However, collaborative knowledge building in this new interaction mode faced some technical and social barriers. According to Stahl (2006), those barriers can open ways for opportunities, if researchers can identify drawbacks of computer-supported collaborative learning environments through experimental studies.

Blended Learning and CSCL.

Blended learning generally is defined as the mode of instruction that combines face-to-face and virtual methods and tools (Bonk & Graham, 2006; Pape, 2010). It has been increasingly implemented in several learning settings (So & Bonk, 2010; Pape, 2010). According to So and Bonk (2010), blending face-to-face and online modes of instructions expand learning experiences of students beyond the classroom in terms of time and space. Pape (2010) argued that the use of online tools to communicate, collaborate, and publish in blended mode supports the development of 21st-century skills students need while extending the school day or year. This combination aims to benefit for the opportunities offered by new technologies, while continuing the critical discourse features of face-to-face instruction (So, 2009). Hence students will have a variety of ways to demonstrate their knowledge.

According to So and Bonk (2010) most of the CSCL contexts are already a blend of face-to-face and online mode, rather than being completely online or face-to-face. Bonk and Graham (2006) suggests three categories for blended learning systems: enabling blend, enhancing blend, transforming blend. Enabling blended forms provide the same opportunities with the face-to-face instruction, and also address some access issues. Enhancing blends also make offer some pedagogical changes while providing online resources addition to face-to-face instruction. Transforming blends make radical changes in the pedagogy by shifting learners from being receivers of the information to actively constructing knowledge. In this regard, this study was designed as an enhancing blended form; since it is not totally changed how student learn, but it enhanced face-to face instruction with online tools. Sharing platforms that were available anytime were created through the online tools in this study for student-student communication and collaboration and student-teacher communication and interaction. Those platforms made considerably changes on how students learn.

Collaboration Technologies in Mathematics Education

A number of studies have been conducted on the integration of web-based technology to enhance student learning with collaboration online (see Beatty & Moss, 2006; Kramarski, 2006; Beatty & Geiger, 2010). One example is Beatty and Moss' (2006) study with fourth graders. They used Knowledge Forum (KF) to provide students with a platform for mathematical discourse. KF was used after students had participated in a 12-lesson instructional sequence to investigate the impact of collaborative problem-solving on the development of students' mathematical skills. Students were allowed to give only text-based entries into the system. Results show that working on a student-managed database supported students' deepening conceptual understanding by providing them with access to each other's theories and perspectives on the problems posed. Those discussion platforms strengthened students' justifying skills by participating in discussions, questioning one another's theories, and comparing ideas in the community of practice they developed. Another study is Kramarski's (2006) evaluation of ninth graders' metacognition while collaborating on problem-solving. For this study, a database was set up to scaffold students: to assist students in self-regulating their cognition, motivation, and behavior, and to give instructions of how to provide mathematical explanations. Kramarski (2006) reported that online support to increase students' metacognition increased students' ability of problem-solving and providing mathematical explanations. In these and similar studies, whole group and peer-to-peer discussions were conducted without the presence of a teacher voice (Beatty & Moss, 2006; Kramarski, 2006; Beatty & Geiger, 2010). Beatty and Moss' (2006) study was in a regular instruction as a supportive platform, and the database in Kramarski's (2006) study was a supplement in an online e-learning context.

Graham and Hodgson (2008) investigated the use of electronic discussion tools in geometry and algebra II classes with high school students from different cultures for about four years in an action research project. They reported higher mathematical understanding and accessibility of content among students. Chat and forums were commonly used by students. The authors claimed that since those online interactions can be printed, they can also be analyzed and used for future instruction by teachers. They provide the teacher a documentation of students' thinking on which additional classroom discussions can be done, especially in the use of mathematical symbols and language. It was suggested that online discussion tools enhanced non-native students' participation giving them more time to think using native students' responses as a template. In addition, comparison was made between traditional classes and classes that used online discussion tools, and results indicated that electronic communication positively affected students' learning.

Studies were also conducted on the use of Web 2.0 technologies in mathematics education. For instance, a group of researchers in Drexel University constituted The Virtual Math Teams (VMT) as part of an effort to investigate group cognition. The purpose of VMT is to determine the value of problem-solving and knowledge building tasks by small groups. During past years, the research team investigated pedagogical, technological, and methodological issues related to online discourse among mathematics students (Stahl, 2008). Text chat and whiteboard systems were used by students in the first years of the project, and then a wiki component was added. Stahl (2008) reported that they have been integrating the use of a wiki into their online environment "to extend synchronous math discourse by small groups to asynchronous math knowledge building by larger communities over extended time periods" (2008, p. 2). The VMT research team found that mathematics can be accomplished collaboratively by students from any level helping each other, building sequentially on each other's moves and exploring together (Stahl, 2010).

Krebs, Schmidt, Henninger, Ludwig, and Muller (2010) argue that wikis are a promising way to improve students' learning while helping them to develop 21st-century skills. In Krebs, Ludwig, and Muller's (2010) study, German middle school students were using a wiki for collaboration and discussions for math projects. Groups of two to four students from different schools were participating in each project for one month. During the process, two face-to-face meetings were scheduled for kick-off and final presentation. Other than this, students were participating in a wiki environment virtually to figure out strategic procedures and approaches on how to solve mathematical problems. Researchers concluded that "real world tasks" using a Wiki can help generate knowledge in practice. The complexity of the tasks requires students to communicate with their peers about the mathematical content for success of learning.

Krebs and Ludwig (2009) examined mathematics education students' use of a wiki as a communication platform for sharing ideas, and for creating, editing, and discussing content in a project-based environment. The projects were completed in addition to regular lecture sessions. They reported that nearly every project group used a mind map to give an overview, so they suggested providing mind maps in wikis on which students can work collaboratively. "A mind map is a multicolored and image-centered, radial diagram that represents semantic or other connections between portions of learned material hierarchically" Eppler (2006). Students in this study demonstrated rare discussion in the Wiki; since the students preferred to discuss the problems face-to-face to clarify unclear points. The authors argue that there must be some specific conditions to be able to observe possible positive effects of Wiki on student learning, like motivating students for discussion. Authors reported that documenting the process of the project could not animate students to reflect on their own learning while solving mathematical problems. They concluded that using a wiki is an adequate platform for mathematical projects, but further studies are needed to determine appropriate ways to ensure student reflection on their own learning.

Below the studies on different aspects of student attitude are presented including: definition of attitude along with a concise explanation of how attitude develop and change and the main influential factors on attitudes; an examination of attitude toward mathematics; an examination of attitude toward learning mathematics with technology; and presentation of effects of technology use on student attitudes in the domain of mathematics based on the reviewed literature.

Attitude Studies in Mathematics Education

Definitions of Attitude.

Attitude is defined as individuals' inclination and disposition toward a person, place, idea, or any other concept (Reed, Drijvers, & Kirschner, 2010). Someone's beliefs, feelings, and behaviors are examined under the attitude topic. Student and teacher attitudes toward subject domains, educational materials, and strategies are seen among the influential factors and predictors of achievement. As a result, attitudes are examined as a correlative with achievement, effective learning, and conceptual understanding in any concept (Galbraith & Haines, 1998; Pierce et al., 2007; Reed et al., 2010).

Literature on student attitudes indicates that there are many ways to define and investigate attitude as a concept. In the 1930s, when the first studies were conducted on attitude, researchers examined attitude as a single dimension regarding feelings or beliefs. Over time attitude has been defined as a multidimensional construct with three interwoven components: "cognitive: expressions of beliefs about an object, affective: expression of feelings towards an object, and conative: expressions of behavioral intention" (Ruffell, Mason, & Allen, 1998, p. 2).

(a) ***How attitudes develop and change.*** Hannula (2002) especially emphasizes the emotion and cognition concepts as the central concepts to analyze attitude. These two concepts are accepted as the main components of the attitude formation in psychology research as well (Crano and Prislin, 2008). While some early theorists emphasizes the cognitive processes in attitude development, like Fishbein and Ajzen 1975; later on more evidence-based research demonstrated the considerable influence of affective processes on attitude development (as cited in Crano & Prislin, 2008). Crano & Prislin (2008) argues that affective and cognitive processes refer to different phases in attitude formation and change. Based on early theories, the authors suggest that: while the affective processes constitute the origins of the attitudes; attitude change has been mostly addressed by the theories which emphasize the cognitive processes through the cognitive based beliefs. On the other hand, recent research proves the contribution of both the affective and cognitive processes on attitude change, like Walther, Gawronski, Blank, & Langer, 2007 (as cited in Crano & Prislin, 2008).

(b) ***What are the biggest impacts on attitudes?*** Maio and Haddock (2009) examines the main effective factors on attitudes under: (a) cognitive, (b) affective, and (c) behavioral influences. Even if for each factor there is a complex process occurring to see the change in attitudes; the authors suggest some basic principles covering all three factors: " (1) attitude change can be elicited by extraneous features of a message or persuasion context; (2) motivation and the ability to form a correct attitude increase the impact of relevant information; (3) persuasion is enabled by a congruence between a persuasive message and accessible knowledge and goals; and (4) persuasion can occur without awareness" (p. 168). The authors argue that even if those four principles reflect the results of the last fifty year's research; there might be certain circumstances in which some of these principles are not operative.

Attitude toward mathematics.

Hannula (2002) recommended a framework to analyze student attitude toward mathematics under four categorical processes:

"1) the emotions the student experiences during mathematics related activities;

2) the emotions that the student automatically associates with the concept 'mathematics';

3) evaluations of situations that the student expects to follow as a consequence of doing mathematics; and

4) the value of mathematics-related goals in the student's global goal structure" (p. 27).

According to Hannula (2002), student attitudes toward mathematics are correlated with the "quality of the teaching and the social-psychological climate of the class" (p. 25). He claimed that there is a causal relationship between attitude and achievement in mathematics directed from attitude to achievement. Ruffell et al. (1998) investigated middle school students' attitudes toward mathematics, and they reported that bad experiences were explained easily in detail by students. The most used words were *nervous* and *bored* to explain a bad experience about mathematics. The students who claimed to like mathematics had a hard time explaining what they like and giving solid examples of good experiences. They perceive mathematics as good when they get it right, which indicates if they experience success on solving mathematics problems they will have positive feelings and beliefs about mathematics. Students emphasized the structure of their mathematics classroom as working quietly by themselves, with little or no help by a teacher or peers and little or no discussion. When we analyze in detailed Ruffell et al.'s (1998) determination of the causes of negative attitudes to mathematics among students, and Deaney, Ruthven, and Hennessy's (2003) examination of secondary school students' perspectives on using Information and Communication Technologies (ICT) in their classroom experiences, we can conclude that technology use as a part of mathematics classes can change students' attitudes toward mathematics. In Deaney, et, al.'s (2003) study, students reported doing tasks more easily, quickly and reliably with high-quality, refinement opportunities for artifacts and ideas, more fun and exciting class work, and a more relaxed relationship with the teacher as the main factors of raised interest in class work and higher motivation when they use ICT in their classes in different subject domains. Mathematics was cited as the area in which most technology use occurred among the all other subject domains. However some activities involving more student interaction rather than involvement using computers reported as more engaging, since they provide students more opportunities while them in terms of content. For example, using SMILE software instead of working with Excel reported as more engaging.

Attitude toward Learning Mathematics with Technology.

Growing use of high-speed technology innovations in the global world and increasing numbers of Internet connections are changing the requirements for education and workplaces considerably (Smith, 2004). Hoyles, Wolf, Molyneux-Hodgson and Kent (2002) reported *mathematical literacy* and *mathematical skills* among the essential requirements of the workplace for many sectors, including electronic engineering and optoelectronics, financial services, food processing, health care, packaging, pharmaceuticals, and tourism. “All the sectors exhibit the ubiquitous use of Information Technology. This has changed the nature of the mathematical skills required, while not reducing the need for mathematics” (p. 10). Hoyles et al. (2002) argue that it is not possible to acquire new mathematical skills by simply combining existing mathematical and ICT skills; instead, it is essential to change our curriculum and teaching strategies according to the need for learning mathematics using technology, so that students can have new mathematical skills gradually. To make this happen, developing positive attitudes toward *learning mathematics using technology* is a critical concern.

When it comes to mathematics and technology in class, and examining student attitudes toward these concepts, more components are included in studies in a broader context. The concepts of attitudes toward mathematics, attitudes toward computers, and learning mathematics with technology in terms of confidence, motivation, and engagement are all contributors in this context (Reed et al., 2010). Galbraith and Haines (1998) claimed that to understand the impact of computers and other technologies on mathematics teaching and learning it is important to investigate student attitudes toward mathematics and the particular technologies used, while Reed et al. (2010) added the kinds of behaviors undertaken when using these tools as the third important indicator.

Galbraith and Haines (1998) determined two scales as technology confidence and technology motivation to measure students' technology attitude (in their study computers instead of technology). The authors named students as confident with technology if they have strong belief of: effectiveness to operate the technology, performing the required tasks for the technology activities, the help of computer for more accurate solutions to math problems, and solving technological problems themselves. For the students who have technology motivations, the authors argue that they "find computers make learning more enjoyable, like the freedom to experiment provided by computers, will spend long hours at a computer to complete a task and enjoy tasking out new ideas on a computer" (p. 278). Pierce et al. (2007) argue that different types of information technologies can contribute improvement in learning and end up with raised engagement with content and positive attitudes toward learning mathematics using technology, bringing more real-world problems into the mathematics classroom. Consequently, the use of different types of technologies will change the context and ambience of mathematics classes, which was also suggested by Deaney et al. (2003).

A scale, The Mathematics and Technology Attitudes Scale (MTAS), was developed by Pierce et al. (2007) to determine the impact of technology use on learning quality and affective changes in middle secondary education, this scale will be discussed in Chapter 3 in detail. This scale covers most of the important components of student attitudes toward mathematics, technology, and learning mathematics with technology suggested by earlier studies including five subscales: mathematics confidence, confidence with technology, attitude to learning mathematics with technology, and two aspects of engagement in learning mathematics. They hypothesized higher student engagement, proposed to develop positive attitudes toward mathematics and learning mathematics with technology over time, and improved learning by including mathematics analysis tools and real-world interfaces as a part of mathematics instruction.

Effects of Technology Use on Student Attitudes in the Domain of Mathematics.

Online technologies. Reviewed literature in mathematics education usually does not directly address the effects of technology use on student attitudes. There are a limited number of studies that reported the change in student attitude as an outcome of technology integration. For example, Ozel, Yetkiner, and Capraro (2008) examined various technology uses in mathematics instruction in the K-12 level. The technologies included calculators, immediate response devices, computers, and Web-based applications. Improved attitudes toward learning, increased student achievement and conceptual understanding, and engagement with mathematics are among the positive effects of technology integration in mathematics education reported by Ozel, Yetkiner, and Capraro (2008). The authors argue that to observe explained positive impacts, it is important to understand how the technology is integrated into the instruction. They suggest three essential factors for effective integration of technology in mathematics instruction as: “a) students and teachers must have equitable access to technology, b) teachers must receive adequate training in the use and implementation of technology within their curricula, and c) teachers must be provided with timely access to technical support so that they are comfortable with integrating technology in their classrooms” (p. 82).

Nguyen, Yi-Chuan, and Allen (2006) investigated the effects of Web-based assessment and practice on improving middle school students’ mathematics learning attitudes. Participants were 74 seventh graders from a middle school in southern Texas. Students were from four class periods taught by the same mathematics teacher. Students in the web-based group (the WP group) worked with online practice tasks in their school computer lab, while students in the paper-and-pencil group (the TP group) worked with the conventional paper-and-pencil practice tasks in the traditional classroom with their mathematics teacher during the math class sessions. The results indicate that the TP group students’ post-attitude toward mathematics remained the same, while the overall attitudes of WP students showed some improvement. In addition, students displayed more interest in doing mathematics and formed a perception that they became smarter in problem-solving with the opportunities of practicing on the computer. The authors suggest that web-based assessment and practice provided students, especially for the students with higher anxiety, to monitor their learning instantly checking their grades whenever they want and they felt less anxious about solving mathematics problems; and the web-based multiple practices helped students to improve their self-assessment and self-regulation.

In a collaborative study between a secondary school teacher and a university professor, Garcia and Romero (2009) investigated the influence of Information and Communication Technology (ICT) on student attitudes and learning. The technologies investigated were: (1) knowledge management software, Moodle in this case, serving as a platform to locate materials and activities designed for the particular mathematics content, and to collect information from students; (2) consulting websites (interactive or not) with mathematical content; (3) a spreadsheet program called Open Office Calc. Two ninth, one tenth, and one eleventh grade class with 79 students in total participated in the study. The focus of the study is emphasized as *mathematical literacy*, which is defined as students' abilities of posing, formulating, and solving mathematical problems while analyzing, reasoning, and communicating their ideas effectively. In this sense the authors defined two types of attitudes: (a) attitudes toward mathematics, which refers to valuing and appreciating the discipline focusing on the affective side of the attitude rather than cognitive; (b) mathematical attitudes, which refers to the general mathematical abilities such as critical thinking, mental openness, objectivity, creativity, and so on. The results indicated improvement in both types of attitudes. In all groups, students had "a more positive view of mathematics as a science, greater interest in scientific work, and more value given to the teaching methods," reflecting the attitude improvement toward math. At the same time students presented greater perseverance, precision, critical thinking, and so on.

Other Technologies. In a recent study by Hekimoglu and Kittrell (2010), researchers examined whether or not seeing a documentary on how mathematicians do mathematics improves student' math self-efficacy beliefs. Two hundred and ninety five college students from thirteen different algebra, pre-calculus, and calculus classes participated in the study. Students watched a 55 minutes documentary on how mathematicians do mathematics and wrote a reflection paper about the documentary at the beginning of the semester. Once the reflection papers collected, 25 minutes discussed were completed on mathematical topics, like the value of doing mathematical proofs. The results indicated that watching the documentary may help students' math anxiety decrease and positive self-efficacy toward learning mathematics increase. The researchers argue that negative student beliefs about mathematics and mathematics that students have had before coming to college prevent successful new learning. Students' fear and resistance can be lessened through the ongoing open classroom dialogue. Then students began to think deeply about their existing beliefs about mathematics and can accept new mathematical messages more easily (Toman and Rak, 2000; Koch and Dollarhide, 2000; as cited in Hekimoglu and Kittrell, 2010).

Oliver (2008) examines the methodology of one post-secondary developmental education (PSDE) basic math class at a private community college in the Midwest in an attempt to improve the college's low pass rate. The theoretical framework of the study is Bandura's (1997) concept of self-efficacy. The explorations of the study include students' perspectives on the process of learning, on the reasons for passing or failing, and on the outcomes in a basic math class. Students were working on a variety of activities such as inserting math answers into the computer program; solving math problems using paper-pencil; reading a section of the multimedia textbook; or getting assistance from one of the computer programs, many multimedia resources, or learning aids during the sessions of that particular math class. Findings regarding student attitude and learning outcomes revealed that participants' attitudes toward math improved. Participants attributed this improvement to the computer-mediated program and module tests. The results on the process of learning revealed that participants had little peer-to-peer interactions, preferred instructor-to-student interactions, and felt less anxiety while working on computers. More peer-to-peer interaction is among the researchers' suggestions. During the final interviews, the majority of the participants who were successful in basic math reported that they were beginning to understand math and they were getting better at math.

Ursini and Sacristán (2006) investigated the implementations of digital technologies in mathematics classrooms. They analyzed the outcomes of a national project called EMAT (Teaching Mathematics with Technology), which has been led by a group of researchers in Mathematics Education, and which aimed at incorporating computational technologies into the mathematical curriculum of secondary schools (children aged 12 to 15 years old). Spreadsheets (Excel), Cabri-Géomètre, SimcCalc-MathWorlds, Stella, the TI-92 algebraic calculator, and the Logo programming language are among the technologies that have been used by students aiming at covering curricular topics such as arithmetic, pre-algebra, algebra, geometry, variation and modeling. The evaluation results of the project indicated that the use of the computational tools has had a very strong positive impact on children's attitudes toward mathematics. Another positive result reported was the changes in classroom dynamics that have modified the traditionally passive attitudes of children and empowered them, giving them a status almost equal (and sometimes even higher than the teacher) when involved in mathematical explorations with the tools by researchers. In another study, Kee and Sam (2006) examined the outcomes of the integration of graphic calculators (GC) in secondary school mathematics in Malaysia to see the impact of GC in the learning of statistics. Results indicated that the engagement of GC in the statistics lessons had motivated students' interest in statistics as well as improved their confidence in the learning process.

In conclusion, studies examined above indicate that there is potential to improve student attitudes by use of technology. However, not all the studies cited above were conducted in secondary education contexts. The technologies used also vary widely, and include both online and offline technologies at the same time. Thus there is a need for research that investigates the influence of one type of technology, for example online technologies, to determine the effects of specific technologies on student attitudes, especially at the high school level.

Conceptual and Theoretical Frameworks

Camp (2001) defines a theory as: "a set of interrelated constructs, definitions, and propositions that present a rational view of phenomena by explaining or predicting relationships among those elements" (p. 13). He argues that conceptual framework explains the natural progression of a phenomenon, while theoretical frameworks are explanations about the phenomenon. In this regard: (a) the conceptual framework that was explained in detail in Chapter 1 is used for this study as a lens to see the bigger picture of where this study fits into the existing body of literature and theories, and (b) the theoretical framework that will be explained in detail below is applied as the concrete theories that will guided this researcher to collect, organize, and analyze the data for this study.

The following three theories were the grounding theories for the argument of using online communication and collaboration technologies in face-to-face mathematics instruction: (1) Stahl's *Group Cognition Theory*; (2) an online learning theory that was developed by Anderson (2004); and (3) Bandura's *Social Cognitive Theory*, specifically *self-efficacy* component. Student learning and students' attitudes toward mathematics and learning technologies during the process were investigated in terms of outcome variables with guidance from those three theories. The first and second theories were directly used to code the qualitative data to answer the first research question, and informed the second research question, too; but they were not directly applied to the second research question. The third theory, Bandura's *Social Cognitive Theory*, was applied to answer the third and fourth research questions which were about student attitude development. Each theory will be explained in some detail below.

Theory #1: Group Cognition Theory.

Stahl (2006) argues that Vygotsky's (1978) emphasis on the role of artifacts in mediated cognition can be used as a framework for analysis of collaborative knowledge building in CSCL contexts. In Figure 2.1, Stahl (2006) recognizes the importance of artifacts in mediated cognition, but also recognizes the influence of language and interaction, which he suggests are additional influential factors affecting learning in collaborative knowledge building, which is also emphasized by Vygotsky in social constructivist theory. In this study, students used multi-step mathematical problem-solving tools to solve and interpret real life situations. Online-Tools classes used VoiceThreads and Google Documents which reflect the communication culture of the 21st century students. The first research question of the study was: How do student-student interaction, communication, and collaboration develop with the support of online technologies in a blended, authentic mathematics curriculum at the high school level?

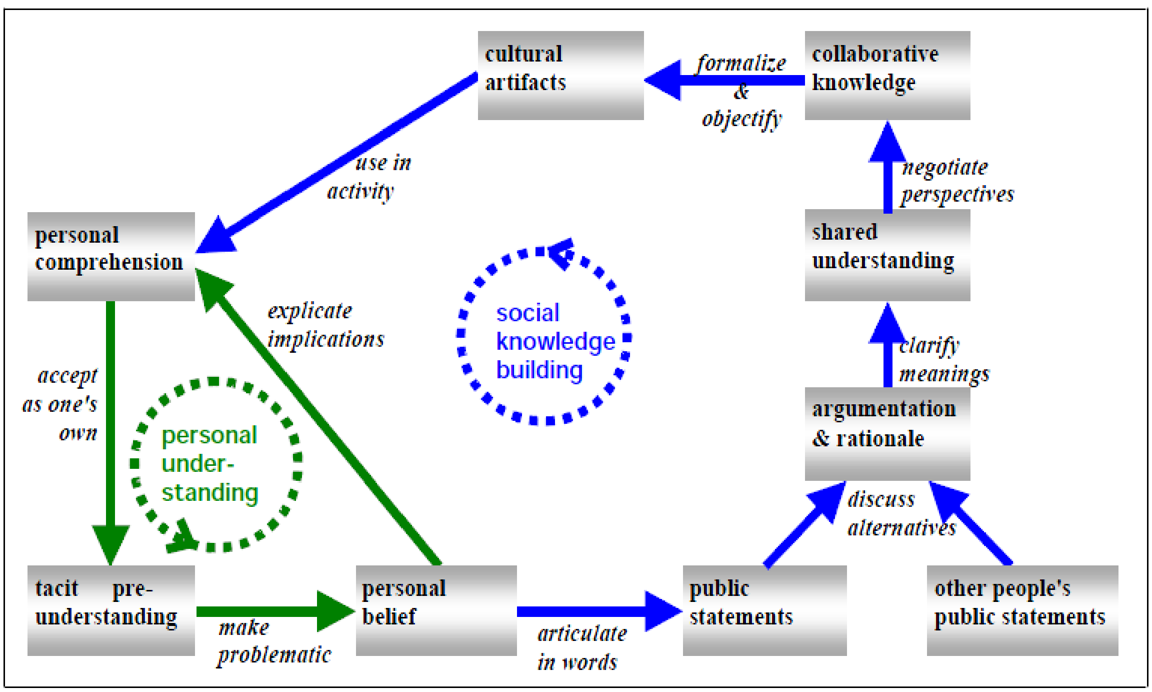


Figure 2. 1. A diagram of knowledge-building processes. Adapted from "Group cognition: computer support for building collaborative knowledge," by G. Stahl, 2006, *Cambridge, MA: MIT Press*, p. 203. Copyright 2006 by Massachusetts Institute of Technology.

Stahl’s schema that is explaining collaborative knowledge building in a computer mediated environment was used to analyze student interaction, communication, and collaboration that developed with support of online technologies in blended instruction. Stahl’s model was chosen as a framework during the preparation stage of this study. Stahl’s model was chosen, because it gives a detailed and concise explanation of a *social knowledge building* process in group work in a computer mediated environment while making connections with *personal understanding* of individuals in the group. One of the purposes in choosing Stahl’s model was to see: which steps of social knowledge building, suggested by Stahl, were being supported by the online tools and the curriculum that was chosen for this study.

The main language that students used to contribute to the problem solving process using the online tools was text-based, but students were also able to use mathematical symbols in their statements. The structure of knowledge building in a CSCL environment, given by Stahl (2006) in Figure 2.1, facilitated making connections and conclusions about student interaction, communication, and collaboration using online tools, VoiceThread and Google Document. While student statements and questions in VoiceThreads reflected more personal understandings, student work as a group in Google Documents reflected how they apply their personal learning and how they build knowledge as a group through collaboration.

Stahl (2006)’s model was the first theory that was chosen to be used in the framework of this study during the very early stages of study preparation and proposal writing. However, during the data collection, the researcher realized that Stahl's model was not explaining all types of interactions between, students, content, and teacher that emerged in this study. It was focusing on the student-student interaction and collaboration, so it was not explaining the other components of the overall whole interaction processes that occurred during the study. So, an online learning theory that was developed by Anderson (2008) was added into the theoretical framework as the second theory.

Theory #2: A Theory of Online Learning.

A blended form of instruction requires converging face-to-face and online instructional methods effectively. Thus an online learning theory that was developed by Anderson (2008) is one of the grounding theories for the argument of using online communication and collaboration technologies in face-to-face high school mathematics instruction. Anderson's model was used as a framework to analyze student interaction, communication, and collaboration that developed with the support of online technologies in blended instruction in addition to Stahl' s schema about knowledge construction. This model included all types of possible interactions that occur in a computer mediated environment. It was employed especially to analyze the interactions between student- teacher, teacher-content, and student-content, which was not explained in Stahl's model. While Stahl visualized possible components of knowledge building that was developed by students during group work, Anderson provided a bigger picture which also captures some other influential interaction types that are directly connected with student-student interaction that emerged with the support of online technologies.

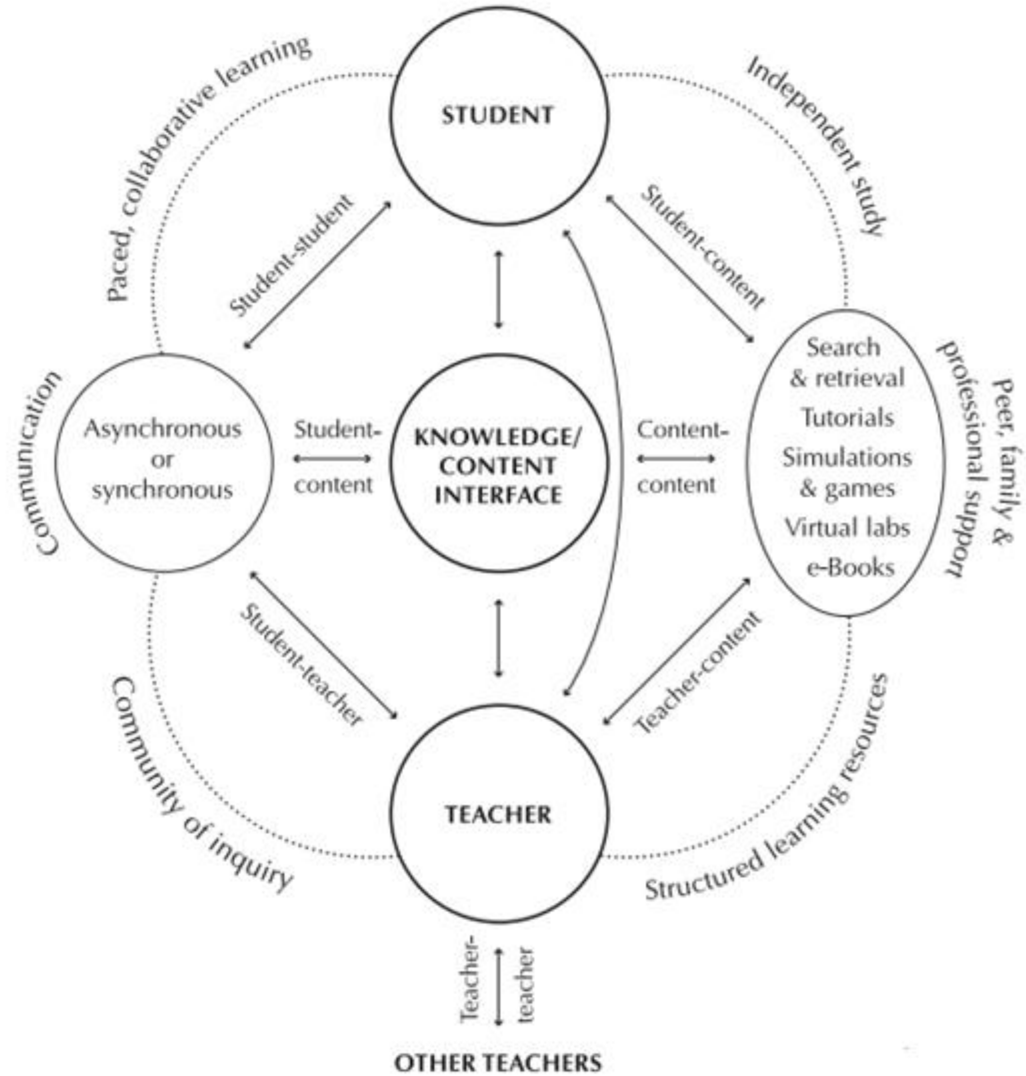


Figure 2. 2. A model of online learning showing types of interaction. Adapted from "Towards a Theory of Online Learning," by T. Anderson, 2008, *In T. Anderson, T. (Eds.), Theory and Practice of Online Learning.* (pp. 45-75), Edmonton, AB, p. 61. Copyright 2008 by Athabasca University, AU Press.

Theory #3: Social Cognitive Theory- Self-Efficacy.

Bandura's (1969, 1977) social learning theory recognizes the importance of interaction and the environment's affect on the behavior of individuals. Social cognitive theory argues that human functioning can be explained by interaction among behaviors, cognitive and other personal factors, and environmental events (Bandura, 1977). The five fundamental human cognitive capacities include: the ability to use symbols, learning through observation, prudence, self-regulation, and self-reflection (Jeng & Braun, 1994). Social learning theory also emphasizes the ability to symbolize and to imagine and to foresee outcomes of our own behaviors. One important aspect of those abilities was identified as self-efficacy by Bandura (1986, 1991, 1997), which defines the ability to estimate our personal effectiveness. Self-efficacy refers to how confident one feels about one's own ability to perform a task or learn a concept. Self-efficacy is one component of self-regulation (Bandura 1997). According to Bandura's (1986) self-efficacy theory, an individual's beliefs about personal capabilities predict future behavior. Self-efficacy theory composes two types of expectancies: *efficacy expectation* refers to the perceived ability to perform a behavior; and *outcome expectation* refers to the belief that outcomes may result from engaging in the specific behavior. Self-efficacy expectation is the primary focus of self-efficacy research, since a stronger relationship appears between efficacy expectation and an individual's actions (Jeng & Braun, 1994).

Bandura (1977) defines *outcome expectancy* as: "a person's estimate that a given behavior will lead to certain outcomes", and *efficacy expectation* as "the conviction that one can successfully execute the behavior required to produce the outcomes”. Thus a strong distinction is made between the two concepts. A person can believe that certain behaviors will lead to particular outcomes, but her belief will not impact her behavior unless she is confident that she can perform the necessary activities. Pajares and Miller (1994) argue that math self-efficacy is more predictive of problem- solving than other strongly related factors such as math-concept, perceived usefulness of mathematics, prior experience with mathematics, or gender. They were examined whether self-efficacy beliefs are stronger predictors than other presumed determinants and common mechanisms in a research study with data gathered on 350 undergraduates from various fields. The results indicated that students’ judgments about their capability to solve math problems were more predictive of their ability to solve those problems than other strongly related factors determined by previous research.

Bandura’s *self-efficacy* component of his *Social Cognitive Theory* was applied to answer the third and fourth research questions, which are related to student attitudes. Student interviews were one of the main sources of data for those questions. Social Cognitive Theory, specifically self-efficacy, guided the researcher in the preparation of questions related to student attitude in the student interview protocol. For example, this question was posed to students: whether there was a change in their math and technology confidence after using online tools in their mathematics class; which was designed to directly reflect their perception about their self-efficacy beliefs. Self-efficacy theory also guided the coding of not only student interviews, but also teacher interviews, teacher reflections and the researcher's observation notes.

Another data source for the third and fourth research questions was the responses from the mathematics and technology attitude scale (MTAS), which was developed by Pierce, Stacey, and Barkatsas (2007). The authors argue that to examine student learning using technology in class for field of mathematics, and examining student attitudes toward this concept; several components should be included. The concepts of attitudes toward mathematics, attitudes toward computers, and attitudes toward learning mathematics with technology in terms of confidence, motivation, and engagement are some of the contributors in this context (Reed et al., 2010). According to Bandura (1997), in complex activities requiring a variety of capabilities, like student attitude development while using technology to learn mathematics, more facets of personal efficacy must be included in the assessment. In this way the predictiveness of perceived efficacy in intellectual development will increase. For example, to estimate how much variance in academic achievement can be explained by one's self-efficacy, the academic efficacy should not be the only factor in assessment. Instead; various facets of self-efficacy such as perceived academic efficacy to regulate learning activity, social efficacy to cultivate supportive social relationships, and self-regulatory efficacy to resist peer pressures for activities should be included in assessment of one's efficacy. In this regard, the scale that was developed by Pierce, Stacey, and Barkatsas (2007) was an appropriate tool to measure student attitude during computer mediated mathematics learning, since they included several contributors of attitude in their scale as suggested by Bandura. To analyze student attitudes while learning mathematics with technology, they included five subcategories: mathematics confidence, confidence with technology, attitude to learning mathematics with technology, affective engagement, and behavioral engagement. All of those five components correspond to Bandura's (1978) definition of self-efficacy, which refers to a person's ability to estimate her personal effectiveness to perform a task or learn a concept.

Summary

A number of studies on technology use in mathematics education have been presented since 1970s in the first part of this chapter. During 1970s, the technology use in mathematics classes started as supplemental tools in existing curriculum. Since 1990s, deeper issues in terms of learning and cognition have been studied. During the mid 1990s the studies were more focused on students' conceptualizations instead of comparisons the instruction with and without the technology and the research started to investigate the impacts of technology use on student learning. Learning games, drill and practice, content applications, and simulations were among the most reported technologies that have been used in classes by those studies during the period. Over time, software and curriculum developers started to seek for more effective and innovative ways to use technology to enhance learning. A lot of studies claimed that technology use may improve student achievement in mathematical concepts (Catley, 2003; Deaney et. al., 2003; Hennessy, Ruthven, & Brindley, 2005; Isiksal and Askar, 2005; Pierce, Stacey, & Barkatsas, 2007), some studies (Artigue, 2002; Guin & Trouche, 1999) argue that learning with technology can be superficial if it only focuses on mastering the skills to use that specific technology instead of learning the content. Artigue (2007), named some major technology uses such as computer algebra system (CAS), spreadsheet, dynamic geometry software, and graphic calculators as the first constructs of technology use in mathematics education, and she claims availability of online reargues opens a new era in technology use in mathematics classes. Peressini and Knuth (2005) presented five leading ways of current technology use in mathematics classrooms for educational purposes as: management tool, communication tool, evaluation tool, motivational tool, and cognitive tool.

Since, the technology use in this study was for communication and collaboration purposes; the second part of this chapter is on Computer Supported Collaborative Learning (CSCL), which deals with the issue of how technology can facilitate the sharing and creation of knowledge and expertise through peer interaction and group learning processes (Resta & Laferriere, 2007). Four major concepts: cooperation and collaboration, knowledge construction and group cognition, blended learning and CSCL, and scripting in CSCL; are included in the section on CSCL research, since they are among the key concepts to understand where this study fits in the literature. The third part of this chapter covers the studies on web-based technologies that have been used in mathematics classrooms to enhance student learning since 2006. Those technologies encouraged student collaboration through the enhanced mathematical discourse (Beatty and Moss, 2006); use of online technologies improved students' metacognitive and problem solving skills, and leaded to higher mathematical understanding (Kramarski, 2006; Graham and Hodgson, 2008). Stahl (2010) argues that problem solving can be accomplished as a group work through peer interactions with the support of online platforms. Krebs and Ludwig (2009) and Krebs, Schmidt, Henninger, Ludwig, and Muller (2010) conducted studies on using wikis in mathematics classes in Germany. The authors reported that even if wikis are a promising way to improve mathetical learning based on their findings; further studies should be conducted to determine appropriate conditions and ways to encourage student collaboration and discourse.

The last parts of this chapter present the definitions of attitude, attitude studies in mathematics education, the studies on the effects of technology use on student attitudes; and the theoretical and conceptual frameworks of this study. The methods, study design, data collection and analysis process of this study are presented in the next chapter (Chapter 3).

CHAPTER 3: METHODS

This section describes the design and methods used for data collection and analysis for this revelatory case study. First, an overview of the study design, and the materials and the tools used in this study, along with an explanation of the rationale for collecting qualitative and quantitative data are presented. Then the timeline, site selection, participants, and sampling; procedures, materials, instruments and data collection; data analysis; research validity and reliability; and limitations to data collection are explained in detail. The research questions guiding this study are:

(1) How do student-student interaction, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum?

(2) How does interaction, communication, and collaboration via online tools impact student learning of an authentic mathematics curriculum?

(3) In what ways are students' emotional, behavioral, and cognitive attitudes affected by using online tools with an authentic mathematics curriculum at the high school level?

(4) Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

Design of the Study

Site Selection.

The researcher’s interest in online tools guided her to study their applications in learning for her dissertation. Since the researcher’s background is mostly related to the field of mathematics, mathematics education was selected as the content area of this study. When the researcher spoke with the principal investigator for the MINDSET grant, Dr. Keene, about the MINDSET project; the project aims, the curriculum they have developed, and their focus group of students (high school) captured the researcher's attention.

Stake (1995) defines two types of case studies as *intrinsic* when the object of the study was obligated and not necessarily chosen by the researcher and *instrumental* when we aim to answer a more general research question by studying a particular case. The choice of the cases in this study is a combination of those two. There was not an obligated specific case for this study, but depending on other choices, like content area and working on a specific curriculum; the options were limited in terms of choosing the case. At first, a specific curriculum that was developed by a project team was chosen for this study, namely the MINDSET project, being taught in some of the high schools in North Carolina. Stake (1995) argues that time and access for field work is usually limited and influential for the choice of the cases, and the researcher needs to pick cases that are easy to get to and hospitable to our inquiry. Because of time and access issues and to increase the contributions of the teachers, teachers in one county who participated in summer workshops for the MINDSET project were asked to participate in this study and use the tools that were developed by the researcher in their instruction. Two teachers from the same county and high school volunteered to participate in this study. They taught the MINDSET curriculum in spring 2011.

Sampling.

Miles and Huberman (1994) argue that *confirming and disconfirming cases, extreme and deviant cases*, and *typical cases* may increase the confidence of conclusions of a case study. Even though this study was completed with volunteer teachers in a revelatory case, sampling for the interviews was critical to make accurate conclusions about the case. Sampling using the *maximum variation* technique was chosen both to identify important common patterns for the entire class and to cover diverse variations within students in terms of different characteristics about student communication, collaboration, learning outcomes, and attitudes. All students of two teachers were asked to participate in this study to ensure maximum variation. Then a group of interest was randomly selected from the volunteers to analyze their documents and conduct one-on-one in-depth interviews.

At the beginning of this study, student interviews were conducted with a group of interest for four classes of two teachers. Various aspects of student characteristics were considered to ensure maximum variation while choosing a group of interest: (a) grades on statewide tests from students' previous mathematics courses to include students with lower, moderate, and higher mathematics ability; (b) group assignments to include at least one student from each small group (from the groups for the Google Document assignments) to examine different collaboration experiences across groups; and (c) scores on technology access and confidence scales to include students with a variety of competencies. According to Miles and Huberman (1994), sampling in qualitative studies may evolve during the field work. To make a more appropriate purposive sampling, the group of interest was expanded during the field work based on the number of volunteer participants who completed the student consent form, and the combination of different criteria that were explained in (a), (b), and (c) above. Those criteria were also applied to generate groups for the Google Document assignments.

Participants.

Two teachers and 79 students at a public high school in North Carolina participated in this study. The student participants were 42 female and 37 male 10^{th}, 11^{th}, or 12^{th} graders from various ethnic backgrounds (see Figure 3.1). An additional 31 students had received the same curriculum and 13 of them used the online technologies; but they were not interviewed; since they did not return the student consent forms or because of the time limitations (see Appendix A for the student consent form).

CASE 1											
Online Tools Class (Teacher A)						***No Tool Class (Teacher A)***					
# of Female Students by grade level			# of Male Students by grade level			# of Female Students by grade level			# of Male Students by grade level		
10^{th}: 2	*11^{th}: 4*	*12^{th}: 2*	*10^{t}: 1*	*11^{th}: 4*	*12^{th}: 3*	*10^{th}: 1*	*11^{th}: 5*	*12^{th}: 6*	*10^{th} :0*	*11^{t} h:1*	*12^{t}: 5*
CASE 2											
Online Tools Class (Teacher B)						***No Tool Class (Teacher B)***					
# of Female Students by grade level			# of Male Students by grade level			# of Female Students by grade level			# of Male Students by grade level		
10^{th} 0	*11^{th} 4*	*12^{th} 7*	*10^{th} 0*	*11^{th} 0*	*12^{th} 6*	*10^{th} 0*	*11^{th} 0*	*12^{th} 8*	*10^{th} 0*	*11^{th} 3*	*12^{th} 8*

Figure 3. 1. Participant gender and grade level demographics. Since the study was conducted at the beginning of semester with Teacher A's classes; a couple of students changed their classes. Because of that, nine students' (6 male, 3 female) grade level information is missing, so they were not included in the Figure.)

Two classes of Teacher A were Advanced Functions and Modeling (AFM) classes and two classes of Teacher B were discrete mathematics classes (see Chapter1- definition of terms for more information about AFM and Discrete Math classes). One of the classes of each teacher was assigned as Online-Tools class and the other as No-Tool class based on teachers' suggestions. Since the implementation for Case 1 was completed at the beginning of the semester, students did not have any grades for the current class. So, the Online-Tools and No-Tool classes were chosen according to their grades for the previous math classes. There were more students who took honors classes in the No-Tool class of Case1 than the Online-Tools class; and No-Tool class students had Bs and Cs; while Online-Tools class students had Cs and Ds mostly. In this regard, the Online-Tools class seemed weaker at the beginning of the semester for the Case 1. For the Case 2, the implementation took place at the end of the semester. So, students had grades from the previous chapters. Based on the teacher report, No-Tool and Online-Tools classes were similar in terms of average class grades for most of the chapters, but Online-Tools class had lower engagement during the class sessions. Online-Tools class also had a lot of absences and more failing students than the No-Tool class.

Both of the teachers who participated in this study were female. Teacher A had fifteen years and Teacher B had two years teaching experience prior to the year when this study was conducted. Both teachers taught the curriculum that was chosen for this study in previous semesters, so they were familiar with the content. Teacher A was teaching Advanced Functions and Modeling (AFM) to two classes; and Teacher B was teaching

Discrete Mathematics to three classes during the semester that this study was completed. They had been using technology in their previous classes; like graphing calculators for equations and graphs. Teacher A had mostly been using a smart-board and smart-slate, and mentioned that she recorded class instruction and put it on the Blackboard course management system in PDF form for her students. Teacher B had used Excel and Fathom, probability software, in her classes. Teaching techniques of the two teachers were similar. Both of them had been lecturing and had group work and group projects for students. One of the classes of each teacher was assigned as the Online- Tools class that was introduced and had access to VoiceThreads and Google Documents, and the other class was assigned as the No- Tool class that was not introduced any online technologies.

The curriculum that was chosen for this study consists of contextual problems that employ multi-step mathematical problem-solving tools to solve and interpret real life problems from business as well as from students' lives. The course assumes that students completed a second-year algebra course and thus met the new "fourth year above Algebra II" mathematics requirement in North Carolina. According to the records that were received from the teachers, all of the students who participated in this study took either Algebra I and II or Algebra I and II-Honors. So, all of them had the required mathematical background in terms of previous mathematics classes for the curriculum that was chosen for this study.

At the beginning of the study, students in Online- Tools classes completed a survey that included questions about their computer and Internet access at home; and their confidence in using technology. According to student responses to the survey questions:

a) All of the students in the two Online- Tools classes had a computer (most of them their own, some of them a family member's computer) at home, and one student in each class did not have Internet access at home. Teachers allowed those students to work on computers that were available in their classrooms during the class period.

b) In the Online- Tools class of Teacher A, all of the students who completed the survey reported that they were very confident in using technology. Four students did not complete the survey. In the Online- Tools class of Teacher B, ten students reported that they were very confident in using technology, while four students rated their confidence lower at five or six out of ten. Two students were absent, and did not complete the survey.

Settings. There were two computer laboratories in the high school in which the training sessions of this study were held and also about forty laptops on carts were available for teachers to reserve for their students. Computer laboratories or laptop carts were used for the training sessions of this study depending on their availability and convenience of location for students and teacher. Since the school had only two computer laboratories, the schedule of the laboratories were always busy. Teachers needed to make reservation several weeks before the training sessions of this study.

During the implementation phase of this study, most of the instruction took place in the classrooms; only the group work for the Chapter 1 project took place in the second computer laboratory. The properties of each setting will be explained below.

Classrooms. Each teacher had their own classroom and both Online-Tools and No-Tool classes were going to those classes for regular instruction. When students need individual computers, Teacher A was taking her students one of the computer labs of the school (the information can be found in next headings); while Teacher B preferred to have laptops on carts in her classroom. In both of the classrooms, books and graphing calculators were available to students. Teacher A's classroom featured one desktop computer with internet connection, and Teacher B's classroom featured two desktop computers with the internet connection at the backside of the classroom. Teacher A had a smart slate in her classroom. Teacher A's classroom was on the second floor and Teacher B's classroom was on the first floor of the same building. Teacher A's classes were in the afternoon and Teacher B's were in the morning during the semester that this study was conducted. Teachers had regular meetings during the semester and they were usually doing the planning together for the MINDSET chapters.

Computer Lab1. The first computer laboratory had thirty desktops with internet connection on the second floor, where Teacher A's class was located. The first part of the training session of Teacher A's Online- Tools class was performed in this computer lab, since it was more convenient for the students and the teacher. Students needed to sign in with their ID and password to be able to use the computers.

Computer Lab2. The second computer lab had about sixty desktops computers and a working area. The second training session for Teacher A's students took place in this computer lab, since computer lab 1 was not available. Some students used desktop computers (not all the desktops were available), and some of them worked in the working area with the laptop carts.

Laptop Carts. There were forty laptops with internet connection available in the school for students by teacher reservation during the class period. For the training sessions, Teacher B's students used laptop cards in the classroom. Some students of Teacher A also used laptop cards in the computer lab2 for the second training session.

Revelatory Case.

The MINDSET curriculum was chosen for this study because of its unique structure. It is an authentic curriculum and includes "real world tasks." Krebs, Ludwig, and Muller (2010) argue that real-world tasks using a Wiki can help to generate knowledge in practice and the complexity of the tasks requires students to communicate with their peers about the mathematical content for successful learning. Google Documents were used like a Wiki in this study as explained in detail later in this document. So the structure of the MINDSET curriculum makes this curriculum an appropriate choice to analyze online communication and collaboration in online tool use. Yin (2003) suggests one of the rationales for a case study as a *revelatory case* where a researcher has an opportunity to observe and analyze a phenomenon previously inaccessible. The MINDSET curriculum is a new curriculum at the high school level, so analyses of high school students' learning of this new curriculum with and without online technologies is a revelatory case.

Procedures.

Research procedures included pre-study tasks (Entering into the Field/ IRB Approval/ Informed Consent Forms), research study procedures, and data collection procedures. Figure 3.2 below presents the research study timeline and processes of the study:

Entering into the Field/ IRB Approval/ Informed Consent Forms.

For the MINDSET project, the Institutional Review Board (IRB) applications were submitted to NC State University in August 2010, with the number 1692 (see Appendix B); and the Wake County School System with the Project No. 797 (see Appendix C) cover this study were approved. The researcher's application to attend classes and make observations as a volunteer in Wake County Public Schools was approved by public schools' system in fall-2010 semester. Informed consent forms for this study were completed by students and teachers at the beginning of the field work of this study (see Appendix A for student and Appendix D for teacher consent forms).

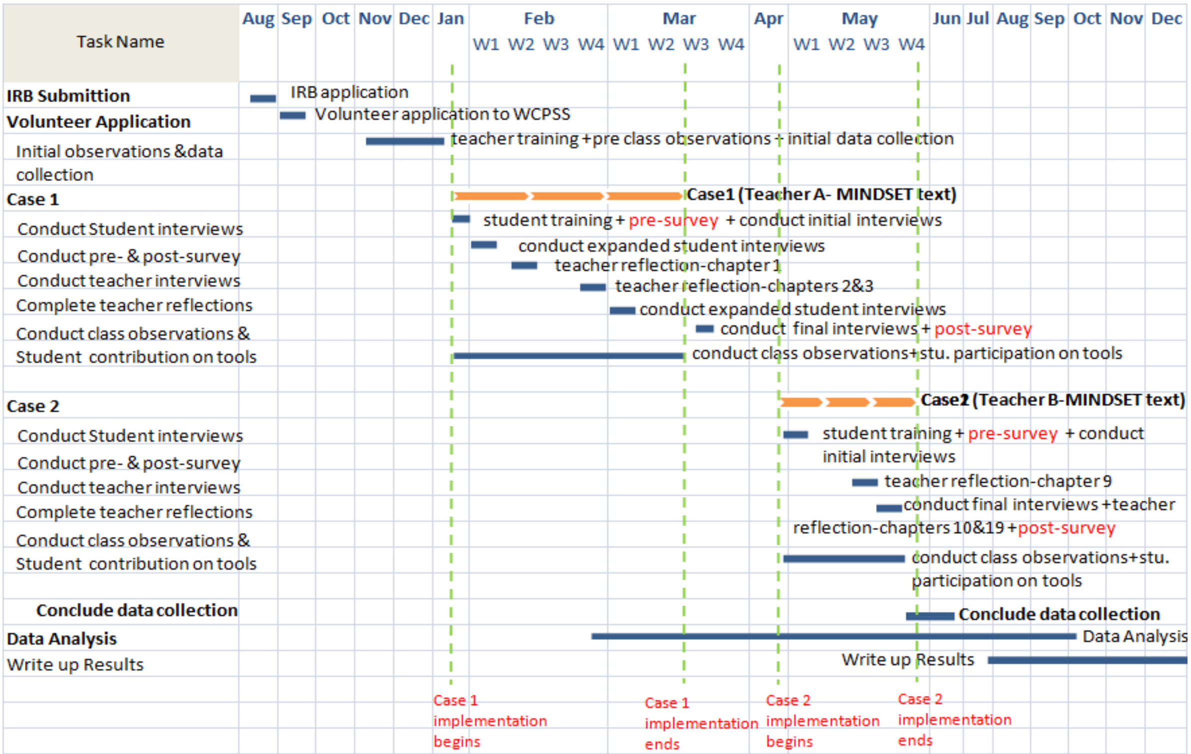


Figure 3. 2. Study timeline. The study started in August 2010 with IRB and volunteer applications and the implementation was between the end of January and the end of May, 2011.

The researcher met with teachers who volunteered to participate in the study in November 2010, and attended some of their classes to make preparatory observations during fall-2010 school semester. Several weeks before the field work, she had a couple meetings with each teacher to train them about using the online tools and inform them about the research process; and to have documents about the students' previous mathematics grades, current class schedules, and lists of the classes for current semester before meeting students. Bogdan and Biklen (2007) suggest that "data are both evidence and the clues" (p. 117). In this regard, the researcher used the preliminary data such as student past grades as the clues for selecting the student interest group for this study.

Research Study Procedures.

The research study was conducted over six months from January through May, 2011 with two cases (see Figure 3.2) with four classes of teachers A and B. The first phase was conducted with two classes (Online- Tools and No- Tool classes) of Teacher A from January through March, 2011; and the second phase was conducted with two classes (Online- Tools and No- Tools classes) of Teacher B from April through May, 2011. Before the implementation for Online- Tools classes, two-step student training was completed. Figure 3.3 visualizes the research study procedures that are explained in detail below.

Student Training. Student training was completed in two sessions: (a) VoiceThread training on the day when students were assigned the first VoiceThread homework, (b) Google Document training on the day when students were assigned the first Google Document homework. During the training sessions: (a) the researcher introduced students to the MINDSET Project Student Website through which they could reach the VoiceThreads and Google Documents prepared by this researcher for the particular chapters, (b) the researcher and the teacher demonstrated how to open VoiceThread and Gmail accounts, (c) students created their VoiceThread and Gmail accounts, (d) students watched a part of the first problem presented in VoiceThread and the researcher demonstrated how to leave comments on the VoiceThread, (e) the researcher demonstrated the basic features of the Google Documents that will be used by students for the assignments.

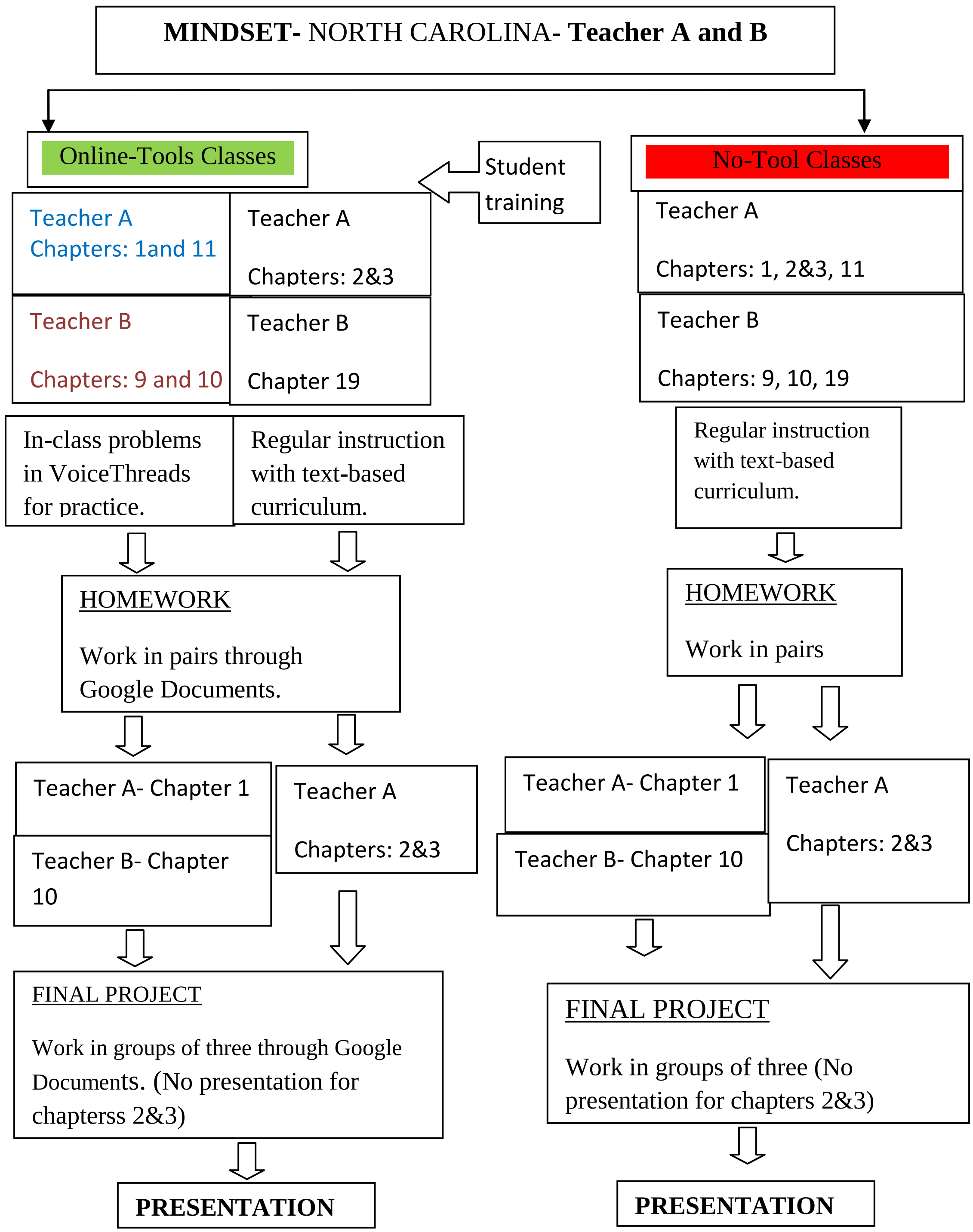


Figure 3. 3. Flowchart of research procedures

Implementation.

At the end of January 2011, the researcher started working with two classes of Teacher A as an observer. This was the first time for the teacher to meet with her classes. After the discussions with the teacher, Online-Tools and No-Tool classes were assigned based on student grades from previous mathematics classes. Student in the Online-Tools class had relatively lower grades than the students in the No-Tool class. The implementation for Case 1 ended in mid-March. At the end of April 2011, the researcher started working with two classes of Teacher B. Teacher B had already known the achievement and attitude of her students in the class. After the discussions with the teacher, students were assigned to the Online- Tools and No- Tool classes based on student attitude in the class; since the achievement level of the two classes were really close to each other based on their previous grades in class. Student in the Online-Tools class had relatively lower attendance and lower behavioral engagement in the class than the students in the No-Tool class. During the implementation, the No-Tool classes used the same content in text-based form, while the Online- Tool classes used online tools for communication and collaboration synchronously or asynchronously. No-Tool class did not have access to the online materials that were provided to the Online-Tools class. The links for the online tools, the Voice Threads and the Google Documents, were shared with students through the MINDSET.student website that was developed by the researcher (see Figure 3.4).

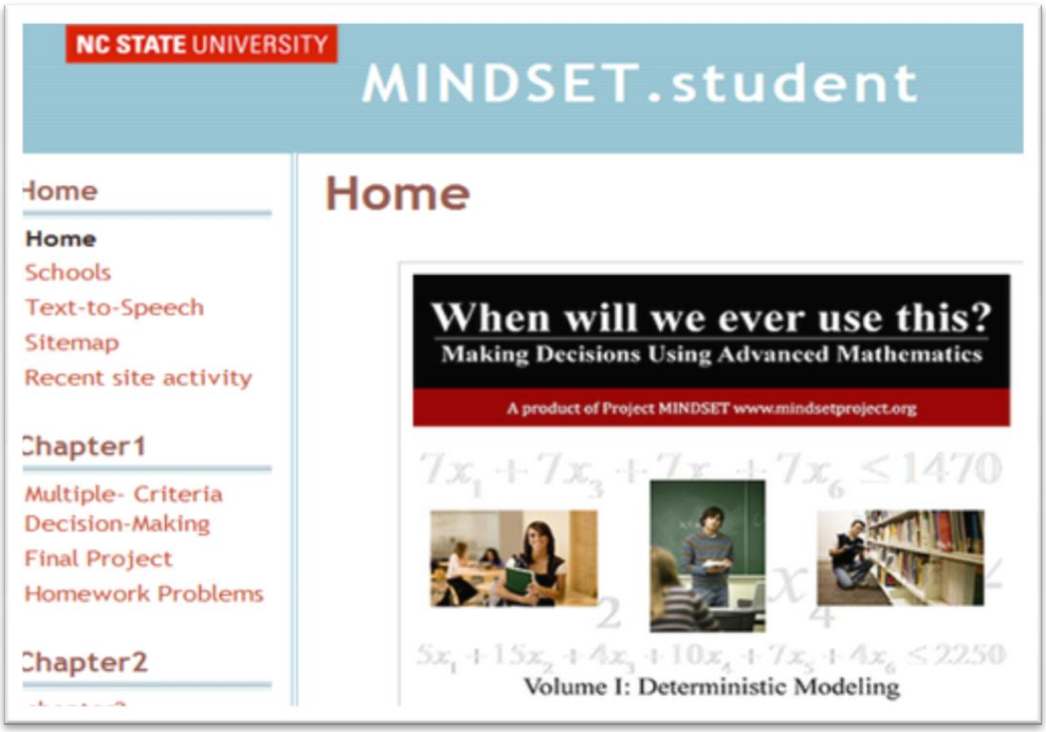


Figure 3. 4. MINDSET Students Website

For each Online-Tools class, in-class problems for two chapters were presented in the VoiceThreads. For Case 1, *Cell-phone Problem* and *College Problem, Investment in Automation* and *Green Tree Energy* were the problems that were presented in VoiceThread (see Figure 3.5 for specific chapters). For Case 2, *Road Reconstruction, Medical Supplies, and Family Dinner* problems presented in VoiceThreads (see Figure 3.5). Each Voice Thread that was given in Figure 3.5 is pictured in Figure 3.6, Figure 3.7, Figure 3.8, and Figure 3.9 below.

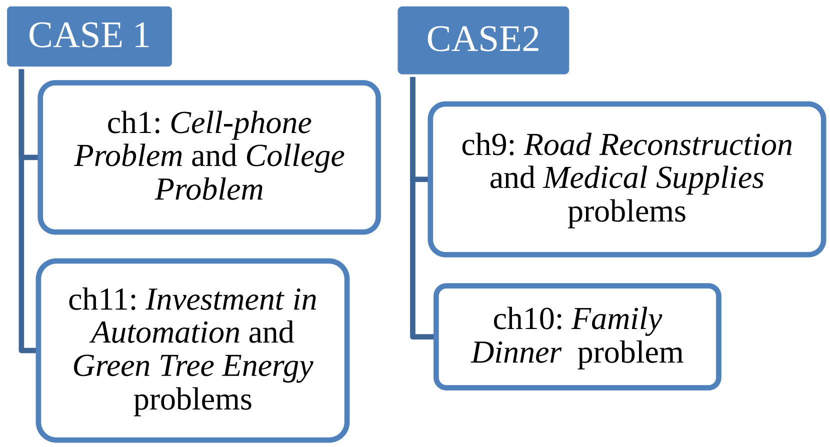


Figure 3.5. Chapters and problems that were presented in the VoiceThreads for Case 1 and Case 2.

Figure 3. 6. Chapter 1 VoiceThread problems for Teacher A's Online-Tools class.

Figure 3.7. Chapter 11 VoiceThread problems for Teacher A's Online-Tools class.

Figure 3.8. Chapter 9 VoiceThread problems for Teacher B's Online-Tools class.

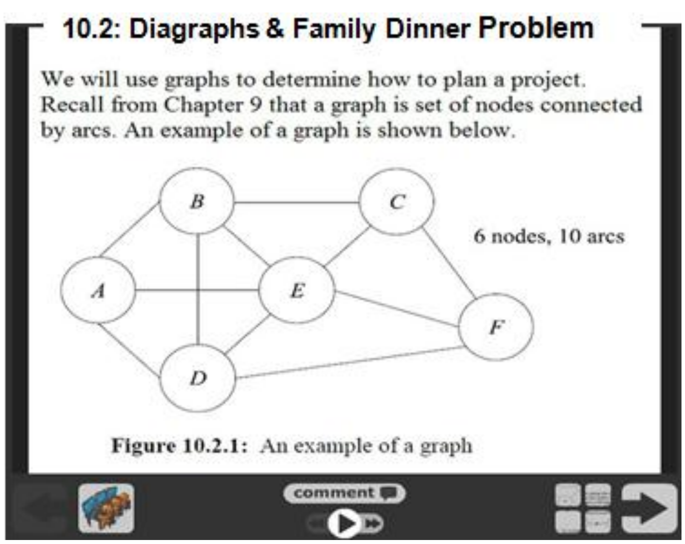


Figure 3.9. Chapter 10 VoiceThread problem for Teacher B's Online-Tools class.

After the face-to-face instruction of each problem, students were given homework. For Online-Tools classes the homework was to practice the problem through the VoiceThread and answer the questions in red by leaving a comment on the particular VoiceThread slides (see Figure 3.10 for an example). For the No-Tool classes the same homework was given in a worksheet. For the rest of the chapters, there were no VoiceThread to practice problems, but students in the Online-Tools classes completed homework problems in Google Documents as groups of two.

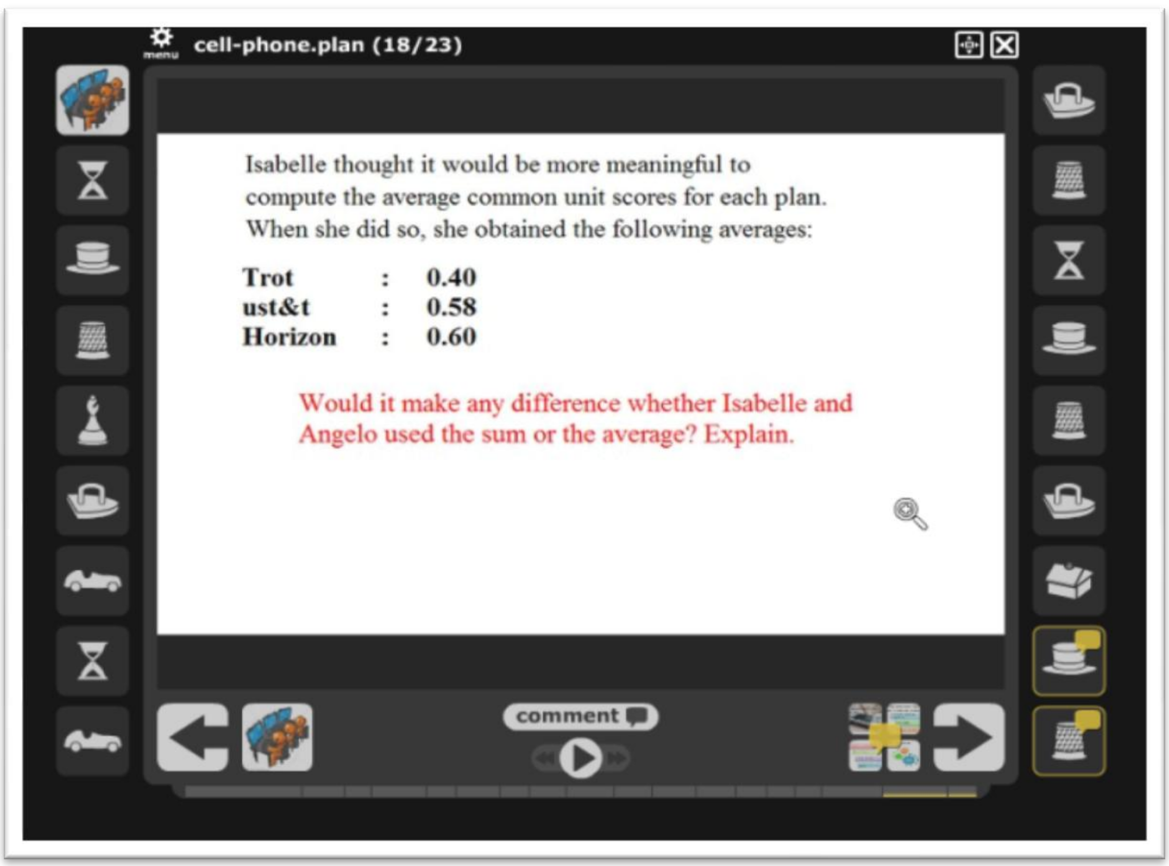


Figure 3. 10. Homework questions asked in red in the VoiceThread presentation.

Google Documents were used for homework problems and the final projects (see Figure 3.11 for specific chapters for which the Google Documents used). Both the Online-Tools and No-Tool classes worked in groups of two for homework problems, and groups of three for projects.

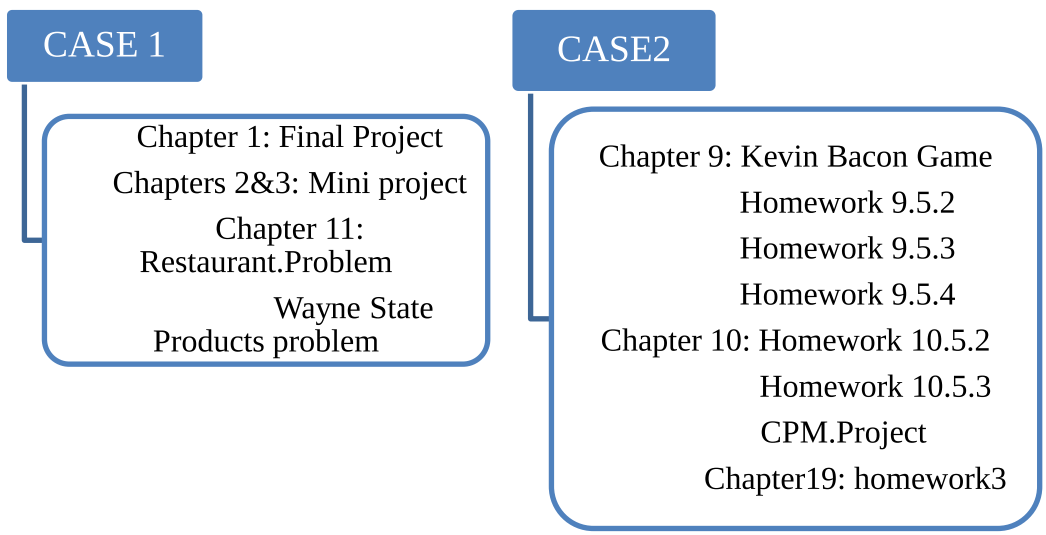
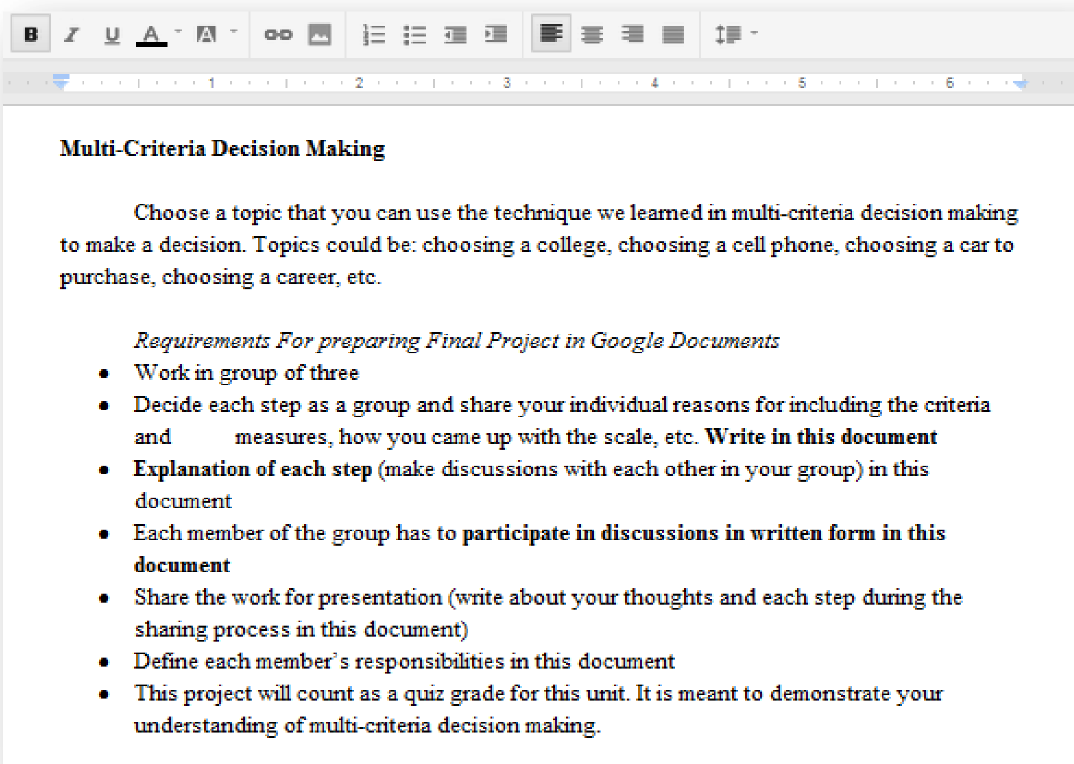


Figure 3.11. The chapters that Online-Tools classes had Google Document assignments.

Google Documents were used like a structured Wiki in which the problem, instructions, and the teacher rubric (see the next section, scripts for the Google Documents, for sample instructions and teacher rubric) were presented for each homework problem or project. The researcher prepared a separate Google Document for each group in Online-Tools classes for each Google Document assignment, and shared the links for the documents through the website or by e-mail with students. Then the students communicated and collaborated through the Google Document that was shared with only their group members to solve the problem. Students were asked to complete all their communications through the document during the solution process. For the first Google Document assignment of each Online-Tools class, students worked on the assignment either in class with the laptop charts or in a computer lab following the training about the Google Documents. Students completed that first assignment with the help of the researcher and the teacher. For the next assignments students were given limited in-class time to complete their homework or project, they mostly worked on the problem solution through the Google Document when they were not in class. They were asked to use the teacher rubric as a reference point during the solution process. Teachers could check each student's participation and contribution to the solution through the revision history of the document. For the final projects, groups in Online-Tools classes were required to solve the given problem as a group in a given period of time, and either submitted the solution to the teacher or made a presentation in class (see Figure 3.3 for the specific chapters for which students made presentations). Duffy and Bruns (2006) reported that sufficient teacher help is essential when students start to use online platforms for the first time, like Wikis. During the Google Document assignments for the final projects, teachers supposed to visit the Google Documents of different groups in class to give feedback about student work, to answer possible questions groups had, and to give directions for the solution of the problems. All student homework and projects were graded using a rubric developed by the teachers, and the final grade was part of the students' official grades. Cubric (2007) emphasized the importance of timely feedback, clarifying the underlying learning and teaching process, and the weight of the Wiki activities in formal assessment as essential factors of student engagement in Wiki activities.

Scripts for the Google Documents.

At the beginning of the each Google Document assignment, the instructions (see Figure 3.12) and rubrics (Figure 3.13) were provided to guide students about how to participate and collaborate, and expectations for problem solutions. Each script was specific to that assignment and developed collaboratively by the researcher and the teachers.



Multi-Criteria Decision Making

Choose a topic that you can use the technique we learned in multi-criteria decision making to make a decision. Topics could be: choosing a college, choosing a cell phone, choosing a car to purchase, choosing a career, etc.

Requirements For preparing Final Project in Google Documents

- Work in group of three
- Decide each step as a group and share your individual reasons for including the criteria and measures, how you came up with the scale, etc. **Write in this document**
- **Explanation of each step** (make discussions with each other in your group) in this document
- Each member of the group has to **participate in discussions in written form in this document**
- Share the work for presentation (write about your thoughts and each step during the sharing process in this document)
- Define each member's responsibilities in this document
- This project will count as a quiz grade for this unit. It is meant to demonstrate your understanding of multi-criteria decision making.

Figure 3. 12. Google Document script sample Part I: Instructions

	Exemplar y	Average	Below Average	Points
Topic submitted in advance	Yes	n/a	No	______ out 5
Were the 8 steps followed?	Yes	n/a	No	______ out 5
Criteria/Measures/Typ e	4 criteria	3 criteria	2 or less	______ out 10
Range of Measures	completely correct	mostly correct	many mistakes	______ out 10
Data collection table (Table 1.3.3)	compares 4 items	compares 3 items	compares 2 or less items	______ out 10
Range of Common Units (table 1.3.4)	completely correct	mostly correct	many mistakes	______ out 10
Common Units (table 1.3.5)	completely correct	mostly correct	many mistakes	______ out 10
Rank ordering, point assignment, and weight calculations (1.3.7)	completely correct	mostly correct	many mistakes	______ out 10
Total score calculations (1.3.8)	completely correct	mostly correct	many mistakes	______ out 10
Interpret Results/Make a Decision Typed Written Summary	well articulated reasoning	why topic, why criteria, what decision you	poorly written	______ out 10

Figure 3. 13. Google Document script sample Part II: Teacher rubric

Materials and Tools

Curriculum.

The particular curriculum developed by the MINDSET research team used in this study. MINDSET[1] **(M**athematics **IN**struction using **D**ecision **S**cience and **E**ngineering **T**ools) is a National Science Foundation (NSF) funded project that has been executed in the states of Georgia, Michigan, and North Carolina and includes many school districts. Mathematics educators, industry professionals, engineers, and mathematicians at three different universities constitute the MINDSET research team. The curriculum developed by the MINDSET research team is an authentic mathematics curriculum in which real-world problems and mathematical models (based on the Operation Research principles from the field of engineering) are introduced to high school juniors and seniors. Students are required to take the basic algebra, geometry, and other baseline classes to take the courses that teach the MINDSET curriculum. Thus, students in these classes had a similar background and have enough mathematical skills to solve the problems in this curriculum. However, the mathematical models introduced for solution of those problems were new to students, so at least the first two or three problems in each chapter explain the way of thinking or procedures of the mathematical model that is necessary to solve the problems in that particular chapter. Further problems in chapters require students to discuss in groups based on the model they have learned in the first part of the chapter. At the end of each chapter, homework problems are provided.

---

[1] MINDSET (Mathematics INstruction using Decision Science and Engineering Tools) is an NSF Funding project in the Division of Research on Learning. Grant number is MINDSET (DRL-0733137)

Tools.

Based on the structure of the chapters in the MINDSET curriculum, two web-based tools, VoiceThread and Google Documents, were chosen for this study. The first one, VoiceThread, is relatively new multimedia software that allows the interactive sharing of images, video, and documents (Holcomb & Beal, 2010). Voice Thread allows users to leave comments in the form of voice, text, or video (see Figure 3.14).

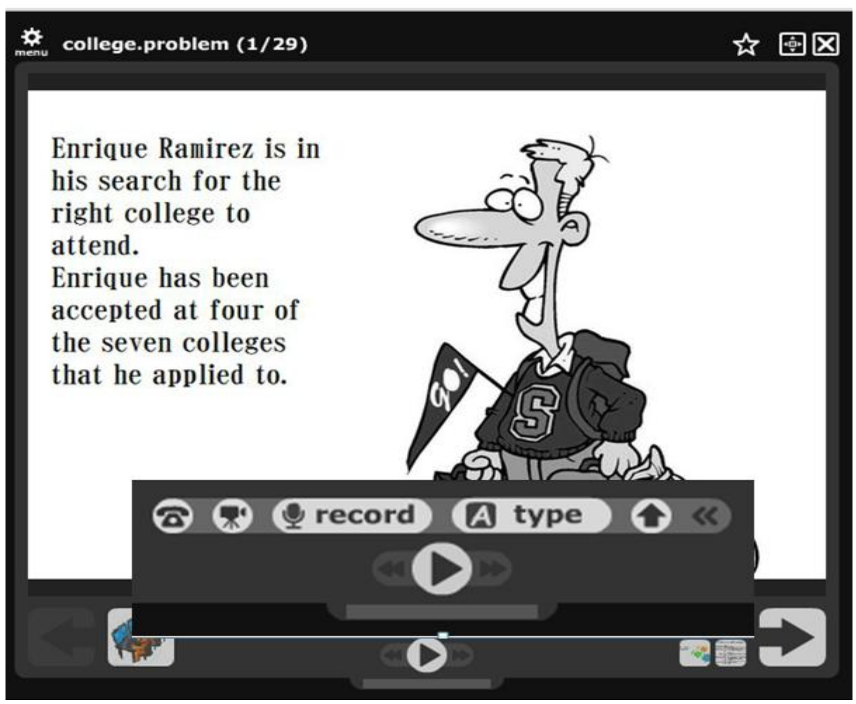


Figure 3. 14. Different forms of commenting on VoiceThread slides

VoiceThread was used for the first part of the chapters where the solution procedure of real-world problems is explained. Problems that were chosen by teachers were presented in individual VoiceThreads. Those VoiceThreads provided students an opportunity to comment on any step to share their ideas or ask questions as a class. The VoiceThread environment also provided a colorful way to present the content with support of pictures and audio to the text-based structure of the MINDSET documents. Figure 3.15 below provides the information about features and affordances of VoiceThread that were applied in this study.

Features	Affordances
Presentation Features	
Ability to annotate a particular slide with text, audio, or video-based comments.	Presenters are able to add related comments, explanation and interpretations to each slide.
Ability to share a presentation online with others.	Presenters are able to present for a real audience. Presenters are able to get feedback easily from others.
Ability (for viewers) to pause the presentation at any point, and jump to a particular slide at any time.	Viewers are able to control the pace of the learning. Viewers are able to view a portion of the presentation multiple times.
Collaboration Features	
Ability to allow a group of users text, audio, or video-based comments on each slide.	Learners can provide feedback or ask questions about a slide. Instructors are able to provide formative feedback on learners' presentations.
Ability for a group of users to draw or write while commenting on a slide.	Learner and instructor can identify specific parts of a slide and make targeted comments.
Ability to view all the comments and discussions on a single slide around the slide.	The entire learning conversation can be visually in one diagram rather than a long text thread.
Moderation Features	
Ability to invite a selected group of users and keep the thread private or public.	The learning conversation can be managed to ensure it is open to the appropriate audience.
Ability to moderate the comments (i.e. creators can pick which comments are shown to others.)	Instructors are able to delete inappropriate comments before they are shown. Instructors are able to decide whether and when to let learners see (and possibly be influenced by) others' comments.

Figure 3. 15. Features and affordances of VoiceThread. Adapted from "Supporting an online community of inquiry using VoiceThread" by F. Gao and Y. Sun, 2010, In C. Maddux, et al. (Eds.) *Research Highlights in Information Technology and Teacher Education*. p.10. Copyright 2010 by Chesapeake, VA: Society for Information Technology and Teacher Education (SITE).

The second web-based tool, Google Documents, is an open source that can be used by anyone who has an e-mail account. Reviewed literature indicates that Wikis are a promising technology for online collaboration. According to Blau and Caspi (2009), similar to Wikis, Google Documents enables collaboration by editing a document written by other students (see Figure 3.16), as well as allows modifications through comment writing without editing the document itself (see Figure 3.17).

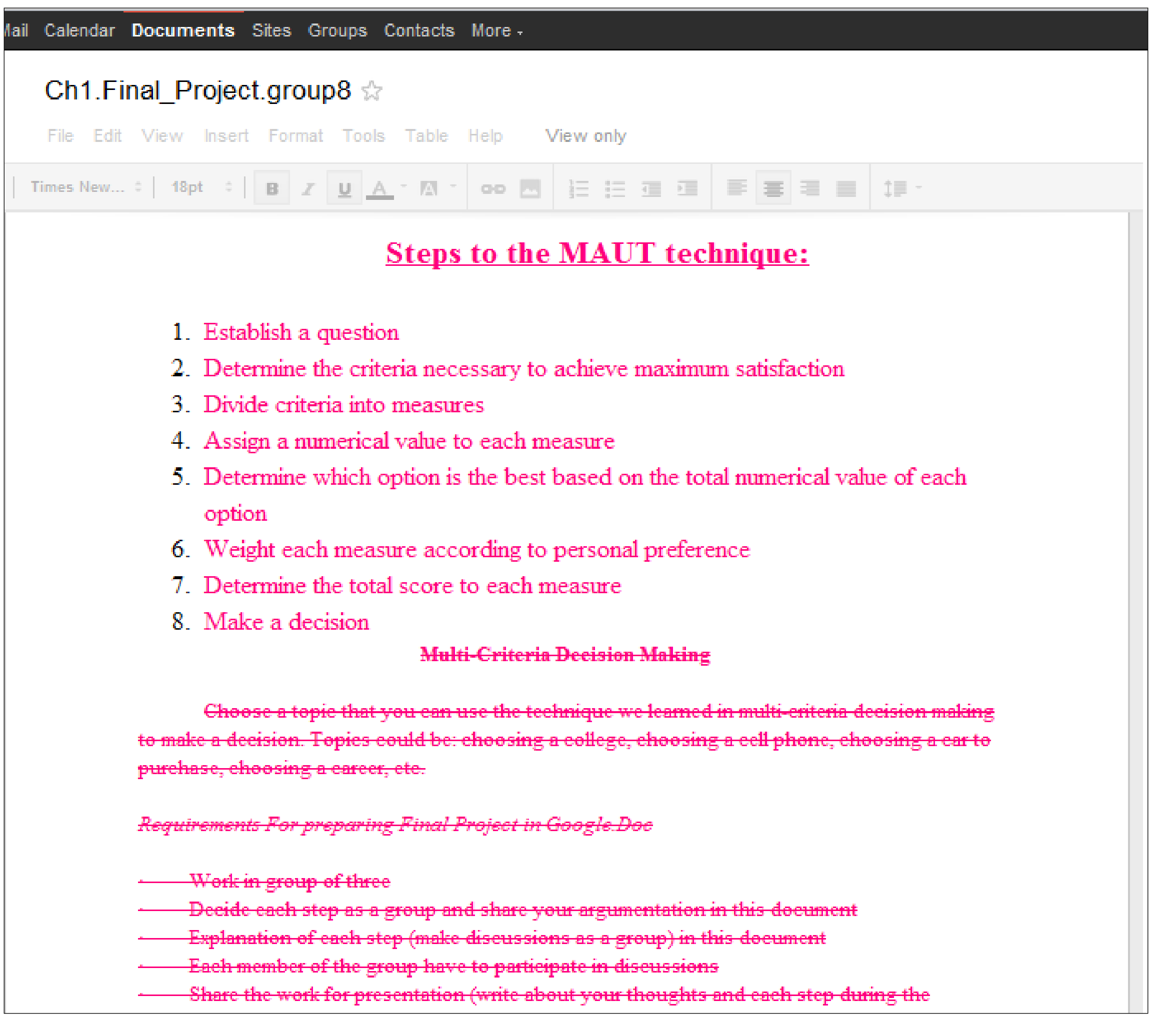


Figure 3.16. Student changes in a Google Document.

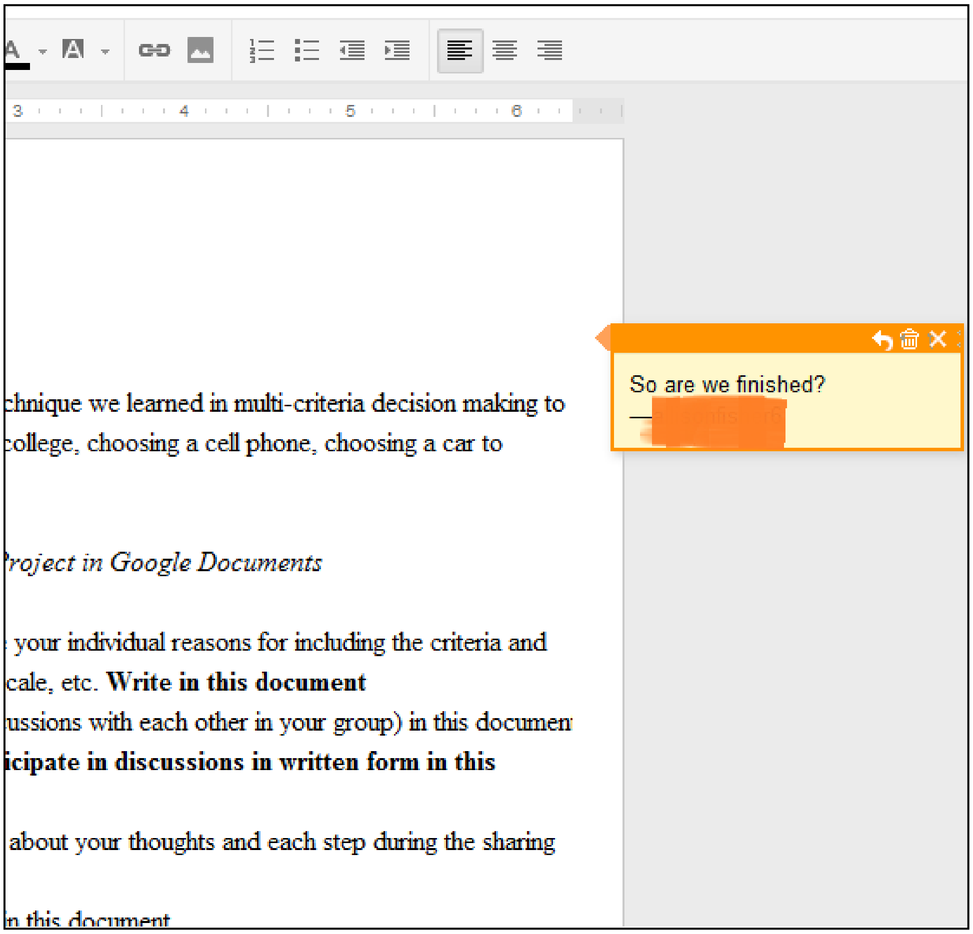


Figure 3.17: A student comment on a Google Document. The text on the left part of the figure chopped of to be able make the student comment big enough to read. The text that was chopped of is not needed here; since the purpose of this figure was to show the student comment.

Figure 3.18 presents the similarities and differences between Wikis and Google Documents. Google Documents are available from any computer with an e-mail account, and allow easy collaboration by sharing options, sharing a document with others as viewers or collaborators, or publishing the document on the Web (Conner, 2008). With features of real-time collaboration by supporting synchronous editing, comment writing, and saving versions of the document, Google Documents affords collective generation of knowledge (Educause Learning Initiative, 2008). They are among the popular and easy-to-use communication and collaboration tools that have been used in schools and campuses.

Characteristics	Wikis	Google Documents
Live, shared space	✓	✓
All team members can have writing and editing privileges	✓	✓
Availability and ease of use from any location	✓	✓
Software download is needed	✓	X
One document to work from rather than multiple copies circulating around the team	✓	✓
Opening a user account required	X	Any e-mail account is fine
Adding plain text is simple	✓	✓
Formats headings, lists, or tables easily	Knowing syntax or system of special punctuation required	✓
Drawing tools	Available as extras in some Wikis	✓
Spell check and other sophisticated editing functionality of a word processing program are available	Some Wikis	✓
Adding mathematical symbols, equations	Available as extras in some Wikis	✓

Figure 3. 18. Similarities and differences of Wikis and Google Documents. Wiki features adapted from “Wikis for supporting distributed collaborative writing” by Wei, C. , Maust B. , Barrick, J., Cuddihy E., and Spyridaki, J. H. 2005. *Proceedings of the Society for Technical Communication 52nd Annual Conference*, Seattle.

Instruments

Qualitative Instruments

The student and teacher interview protocols, and the teacher reflection probes were prepared based on the Bandura's theories and the reviewed literature.

Interview Protocol Forms- Student. One semi-structured interview with three parts was conducted with each student who participated in this study (N= 69). One interview protocol was provided in Appendix E in three parts including all the questions that was in the interviews: *Part I*; demographic questions containing student experience with mathematics and technology before the class they had been taking and their general attitude and confidence about mathematics and technology, *Part II*: Questions about student experiences with the online tools and their perceptions about the effects of the online tools on their learning and attitude, *Expanded Interview*; Questions about student participation and preferences using online tools. Each student in the Online-Tools classes was asked all twelve questions in Part I and Part II. Depending on some specific type of communications between students in their group and their preferences about using the online technologies two additional questions were asked to the students. Each student in comparison groups were asked all the questions in PART I of the interview protocol, question 12 in the PART II of the interview protocol, and some expanded interview questions.

Interview Protocol Forms- Teacher. Two semi-structured interviews were conducted with each teacher. The first interview took place at the beginning of the study, while the second interview took place at the end of the study. The interview protocol form for the teacher interviews are provided in Appendix F. The prompts in the first teacher interview contained demographic questions like teaching experience, experience with technology in their previous classes, experience with the curriculum, and expectations for students when they use online technologies. The second interview prompts contained questions about teacher perceptions of student experience with online technologies and their impact on their learning and attitudes, and similarities and differences in terms of their attitudes in Online-Tools and No-Tool classes.

Teacher Reflection Probes. Guiding probes to guide teachers for their reflections was prepared by the researcher and given to the teacher at the beginning of the study (see Appendix G for teacher reflection probes). The same reflection probes form was completed by teachers for each chapter completed in MINDSET. Reflection probes were related to teacher perceptions about student learning and attitudes during each specific chapter.

Observation Guidelines. An observation guideline was used for the early class observations to collect data especially about the presage variables such as classroom context, student characteristics, and instructional material. Headings in the document also guided the researcher to take notes of the emerging themes about any of the variables.

Quantitative Instruments.

Attitude Questionnaire. The Mathematics and Technology Attitude Scale (MTAS), which was developed by Pierce, Stacey, and Barkatsas (2007), was used for the quantitative data collection of this study. This scale consists of 20 short items under five subscales: "mathematics confidence [MC], confidence with technology [TC], attitude to learning mathematics with technology [MT], affective engagement [AE], and behavioral engagement [BE]". Developers of the scale suggest tailoring MT items according to unique technology tools that will be used. So, only the MT subscale of the MTAS was modified to include *technology used in mathematics* instead of *graphic calculators* for the needs of this study. Pierce et al. (2007) reported that:

> "A Likert-type scoring format was used for each of the subscales: MC, TC, MT and AE. Students were asked to indicate the extent of their agreement with each statement, on a five-point scale from strongly agree to strongly disagree (scored from 5 to 1). A different but similar response set was used for the BE subscale. Students were asked to indicate the frequency of occurrence of different behaviors. A five-point system was again used – nearly always, usually, about half of the time, occasionally, hardly ever (scored again from 5 to 1)" (p. 293).

Validity and Reliability of MTAS.

The Mathematics and Technology Attitude Scale (MTAS), which was developed by Pierce, Stacey, and Barkatsas (2007), was used for the quantitative data collection of this study. The authors reported that "the content validity and face validity of the scale are assured by the development process" of the scale. The scale was tested with 350 students. The statistical analysis from the testing data indicates that "data satisfies the underlying assumptions of Principal Components Analysis and that together five factors (each with eigen value greater than 1) explain 65% of the variance; with almost 26% attributed to the first factor, MC" (Pierce, Stacey, & Barkatsas, 2007, p. 294). The Cronbach's alpha values were reported as: MC, .87; MT, .89; TC, .79; BE, .72 and AE, .65, which indicates “a strong or acceptable degree of internal consistency in each subscale” (Pierce, Stacey, & Barkatsas, 2007, p. 294).

Data Collection

Yin (2003) argues that a case study relies on multiple sources of evidence, and benefits from the prior development of theoretical propositions to guide the data collection and analysis. For this study, multiple data sources were used to collect data about student attitudes, problem-solving, communication, collaboration choices, activities, and student mastery of content. In addition, the theoretical framework, given in the second chapter, guided the researcher to analyze: (a) student communication and collaboration with online tools in the Online- Tools classes, and (b) attitude development in Online- Tools and No-Tool classes.

Interviews with student interest groups and teachers, class observations, the content of online tools (such as comments on VoiceThreads and electronic or hard copies of Google Documents), teacher reflections, teacher documents presenting student achievement in terms of their grades, and attitude questionnaire are sources of data for this study. Each data source is explained in detail below.

Rationale for Collecting Qualitative and Quantitative Data.

To help the reader understanding the terms and procedures that were explained in the data collection section, the rationale for collecting qualitative and quantitative data is examined here (just before my data collection section).

For the attitude component, the researcher sought to examine two types of attitude development:

Research Question (3): In what ways are students' emotional, behavioral, and cognitive attitudes affected by using online tools with an authentic mathematics curriculum at the high school level?

Research Question (4): Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

The quantitative data was collected to examine student attitudes in both groups before and after the instruction to capture the possible development of positive attitudes applying pre- and post-questionnaires. The results of the quantitative analysis provided evidence for: (a) the overall attitude similarities and differences between the groups, and (b) the overall improvement of attitudes for the Online- Tools classes before and after using the online tools. Creswell and Plano-Clark (2007) argue that the triangulation design could be used to validate and expend quantitative results with qualitative data. The researcher has used qualitative data for triangulation of the results of quantitative analysis and to examine in depth the similarities and differences between groups and the development of student attitudes in the Online- Tools classes.

For the student learning component, the focus of this study is:

Research Question (1): How do student-student interaction, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum?

Research Question (2): How does interaction, communication, and collaboration via online tools impact student learning of an authentic mathematics curriculum?

The qualitative data was collected using multiple sources for the cases that were examined for this study. Stake (1995) argues that cases in education can be people and programs which are similar to other persons and programs in many ways and unique in many ways, and the researcher may be interested in them for both their uniqueness and commonality. The researcher was interested in both in this study: (a) students' experience about using the online tools that will be offered in the case study in respect to their unique affordances and opportunities they may provide to students, and (b) what student experience with those specific tools can tell us about the general theories and empirical understanding and development of CSCL research in mathematics education. So a qualitative case study with multiple data sources is appropriate to answer the research questions and allowed researcher to make an in-depth analysis about student interaction, communication, and collaboration with peers, teachers, and technology tools and their attitude to mathematics and technology.

Data Sources.

Figure 3.19 below shows all data sources and how they align with the research questions (RQs) and Figure 3.20 presents three types of variables of this study, and the units of analysis and data sources of those variables.

Data Sources		RQ1	RQ2	RQ3	RQ4
Class Observations and Researcher Memo TA (N=18) ; TB (N=10) CA (N=15) ; CB (N=7)		✓			
Student Interviews TA (N=26) ; TB (N=15) CA (N=10) ; CB (N=18)		✓	✓	✓	✓
Teacher Interviews (Two interviews with each teacher)		✓	✓	✓	
Teacher Reflections (Teacher A,2; Teacher B, 3 reflections)			✓	✓	
Attitude Questionnaire TA (N=19) ; TB (N=15) CA (N=22) ; CB (N=19)				✓	✓
Documents: TA: 4 Google Doc.+ 4VoiceThread assignments TB: 6 Google Doc.+ 3VoiceThread assignments	-*Google Documents*	✓			
	-*Student Grades* TA&CA: 8tests, 2projects,3quizes TB&CB:9tests, 1project,8quizes		✓		
	-*VoiceThread Comments*		✓		

Figure 3. 19. Alignment of data sources with the research questions.

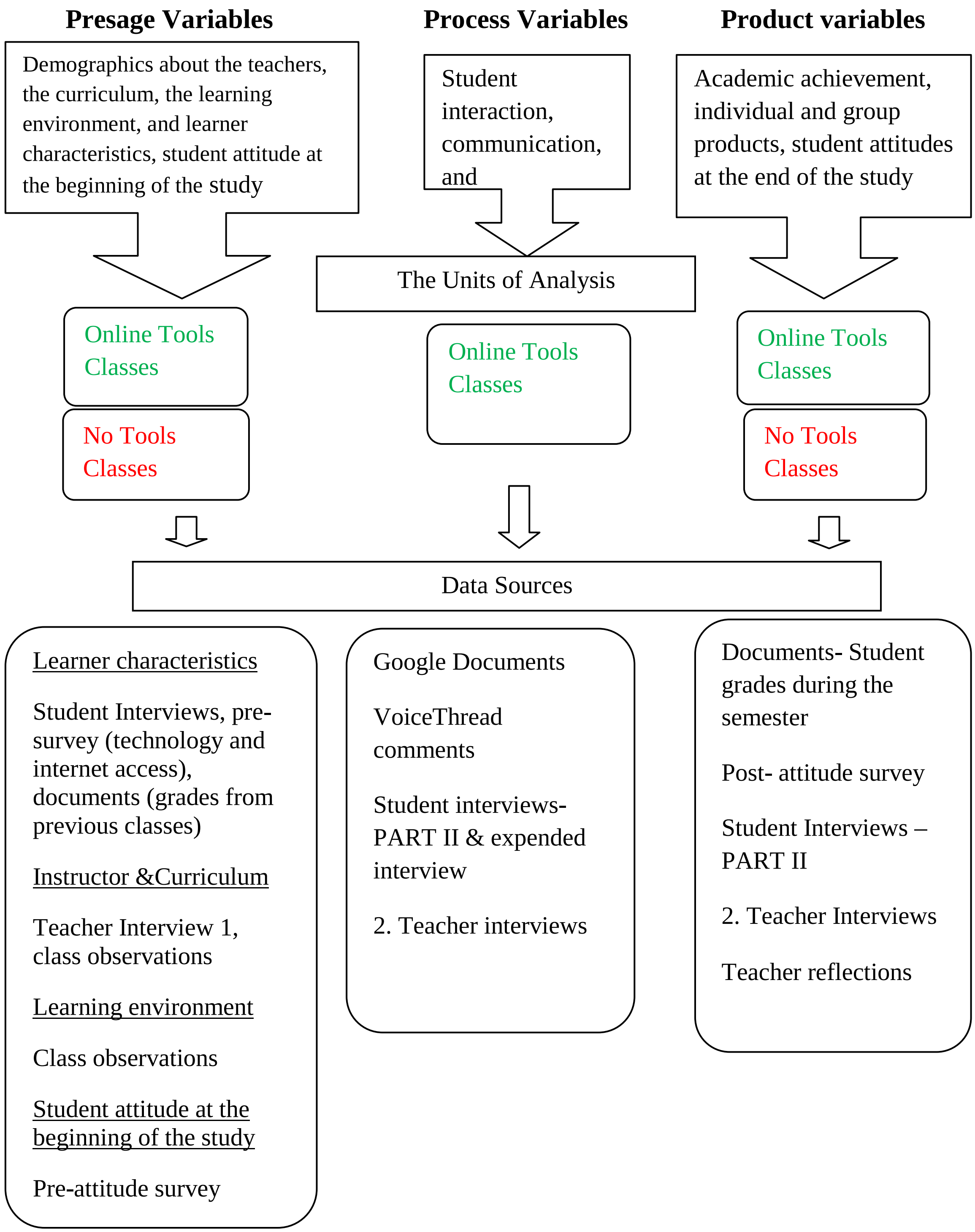


Figure 3. 20. Flowchart of variables and data sources.

Data Collection Procedures.

The data collection period was outlined in Figure 3.20. Students completed the attitude survey on the first day of the study. Then they were assigned the first VoiceThread and the first Google Document assignments in the first week. The student comments on VoiceThreads and student work in Google Documents were saved automatically by the tools themselves, and were available for the researcher anytime. VoiceThread has a system that was used to send the researcher e-mails that reported the name of the student who had commented on a VoiceThread, which VoiceThread she/he commented on, and the time that she/he commented. So, the researcher got daily e-mails about student participation in VoiceThreads. Google Document has a feature recording each revision of a document, the time the document was revised and the e-mail of the person who revised the document. Later in data collection and data analysis process, the researcher examined these VoiceThread e-mails, the comments on the VoiceThreads, and the Google Document revision history to guide the further data collection and the analysis. The PART I and PART II of the student interviews were conducted at the beginning and at the end of the field work with each class. In addition, expanded student interviews were conducted as needed. The first teacher interviews were completed with the teachers in the first week of the field work and the second teacher interviews were completed at the end of the field work, and teachers completed a reflection after the instruction of each chapter.

Case 1: Teacher A's classes			
Week 1: 1/25- 1/30	**Week 2**: 1/31-2/6	**Week 3**: 2/7-2/13	**Week 4**: 2/14- 2/20
Attitude-survey completed PART I student interview Teacher interview 1	Expanded Student interviews (only Online-Tools class)	Teacher reflection- chapter 1	
Class observation			
Constant student participation and contribution saved in VoiceThread and Google Documents (only online-tools class)			
Week 5: 2/21- 2/27	**Week 6**: 2/28- 3/6	**Week 7**: 3/7-3/13	**Week 8**: 3/14- 3/18
Teacher reflection- chapters 2&3	Expanded student interviews (only Online-Tools class)		PART II student interview Teacher reflection- chapter 11 Teacher interview 2
Class observation			
Constant student participation and contribution saved in VoiceThread and Google Documents (only Online-Tools class)			
Case 2: Teacher B's classes			
Week 1: 4/29- 5/1	**Week 2**: 5/2-5/8	**Week 3**: 5/9-5/15	**Week 4**: 5/16- 5/19
Attitude-survey completed PART I student interviews Teacher interview 1	PART I student interviews	Teacher reflection- chapter 9	PART II and expanded student interviews Teacher reflection- chapter 10 and 19 Teacher interview 2 Documents presenting student grades throughout semester received from both teachers
Class observation			
Constant student participation and contribution saved in VoiceThread and Google Documents (only Online-Tools class)			

Figure 3.21. Data collection timeline.

Each data source will be explained in detail below:

Student Interviews. Semi-structured student interviews were among the primary data sources of this study. Student interview prompts were related to all four research questions of this study. A single –piece interview protocol was prepared including three parts: Through PART I of the student interview, data have been collected about baseline information of students; like prior experiences with mathematics, with technology, learning mathematics with technology, and collaboration tools, preliminary attitudes towards mathematic and technology (presage variables). PART II of the student interview provided the researcher the opportunity to hear about his or her experience of using online tools in the mathematics class with their own words. This data was used to examine: (a) student perception about the interaction, communication, and collaboration using online tools; attitudes through using online tools (Related to RQ1); (b) student perception about the impacts of using online technologies on their learning of the content of the class based on his or her experience (Related to RQ2); (c) student perception about the impacts of using online technologies on attitude towards mathematics and technology (Related to RQs 3&4). The questions in the *expanded interview* were developed after a Google Document assignment, where different participation levels among groups were observed. In response to this, the researcher conducted an extra interview with students from different groups to hear about their communication and collaboration during the particular assignment.

Teacher Interviews. Teacher interview data consist of the teacher's experience, thoughts, and evaluation of using online tools in her class, and her perception of student learning and attitudes during the implementation phase of this study. For the first and second research questions of this study, teacher interviews were used for triangulation of the data collected through the student interviews and document analysis. For the fourth research question of this study, teacher interviews were used for triangulation of the data collected through the student interviews and attitude questionnaire.

Teacher Reflections. While teacher interviews provided detailed information about the process from the teacher's point of view, teacher reflections were about the teacher's perception of student attitudes and learning of the particular content of each chapter. Those weekly reflections have provided information to triangulate the information that was collected through other sources, like interviews and document analysis. They also gave the teacher the opportunity to reflect on each particular chapter.

Attitude Questionnaire. In Pierce, Stacey, and Barkatsas (2007)'s scale, MTAS, mathematics confidence refers to "students' perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics" (math self-efficacy) (p.290). Technology confidence refers to feeling assured in operating computers, belief for mastery of computer procedures required of them, and confidence of resolving the problems themselves when a computer problem occurred (technology self-efficacy). Affective engagement deals with how students feel about the subject; and behavioral engagement deals with how students behave in the process of learning the subject. Finally, "attitude towards use of technology for learning mathematics" refers to the degree students perceive the use of computers in mathematics aids their learning of mathematics and contributes to their achievement in mathematics. Hence the MTAS related to third and fourth questions of this study.

Students who participated in this study completed the MTAS at the beginning and at the end of this study. The pre-survey and post-survey results of the online tools classes used to make a triangulation with the student interview data to evaluate the possible attitude changes during the study. At the same time pre-survey and post-survey results of all groups used to make a triangulation with the student interview data to evaluate the possible attitude differences between Online- Tools and No- Tool classes.

Documents.

Google Documents. Google Documents, which was one of the online communication and collaboration tools that was applied in this study, were another source of data. Student participation in the Google Documents was recorded through the revision history of the document itself. Those records informed the first research question by monitoring individual student participation and contribution to the assignment (See Figure 3.22). The records of student participation were also used for a triangulation component with student self-report from the interviews about the impact of using online technologies on their learning; which informed the second research question. The researcher also looked at the electronic Google Documents that were created by each group to evaluate the assignments and their revision history during the study. This led the researcher to do an expended interview with students regarding communication preferences of different groups, like communicating with each other face-to-face or through the chat.

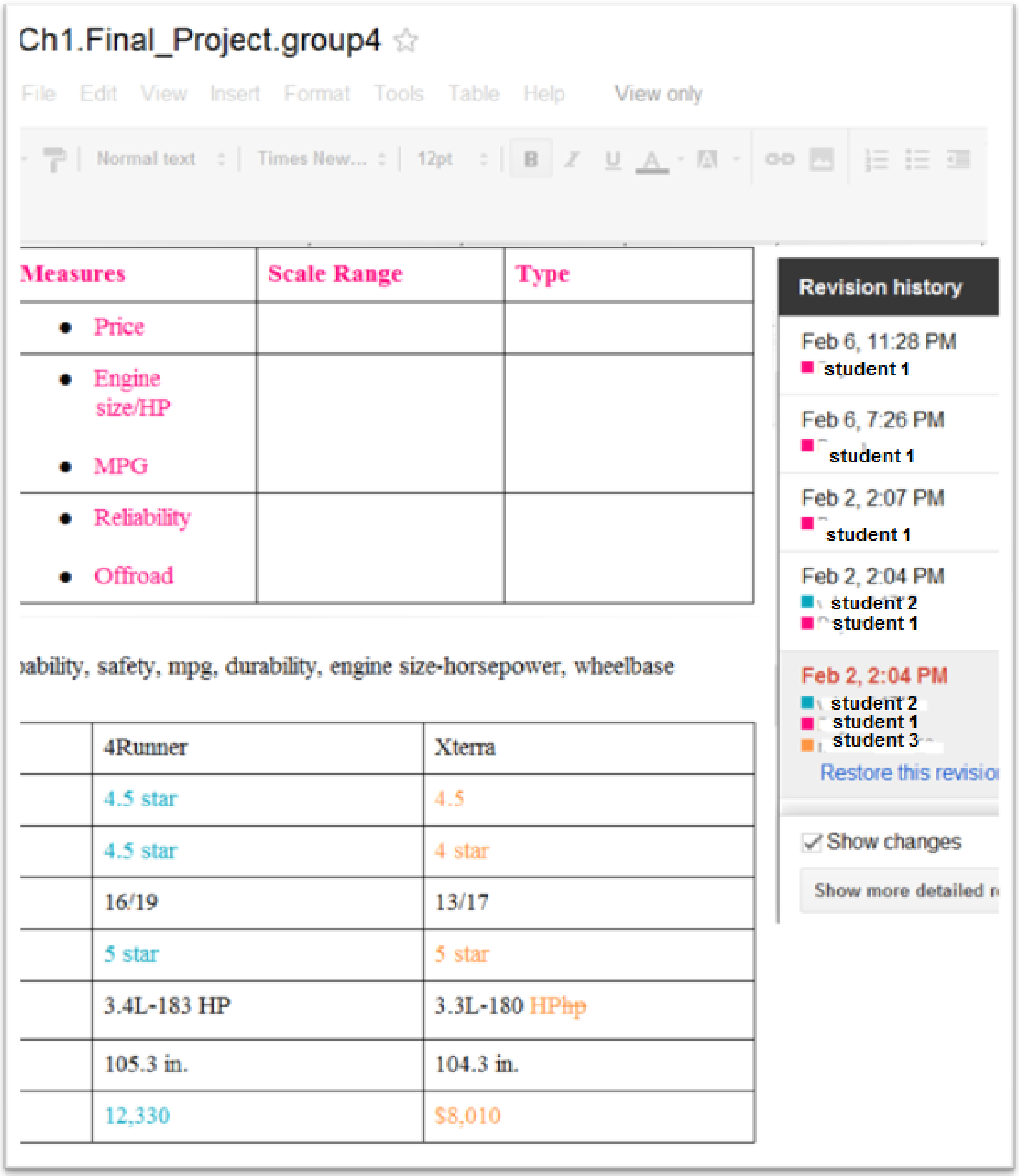


Figure 3.22. Google Documents recorded individual students' contribution through the revision history.

Student Grades. Complementary data sources of this study were (a) student grades for the tests, quizzes, and projects completed through the semester and (b) for the previous semesters. (a) Student grades during the semester were recorded in two separate folders: (1) during and (2) before or after the implementation of this study. All the grades were ranging from 0 to 100. There were 4 test, 2 projects and 1 quiz grade for each student. The grades during the implementation, and before or after the implementation were averaged for each individual student in each of the four classes. They were recorded in a table to evaluate the impact of online tool use on each individual student's achievement and make triangulation with student perceptions about their learning. Student participation for using online tools was recorded in the same table from the interview codes. Grades were also averaged for each class to make comparisons between classes. Those student grades informed the second research question of this study in terms of how student learning was affected by use of online tools in terms of their grades. All the problems in tests, quizzes and projects were developed and assessed by teachers. The rubrics for assessment were prepared by teachers as well.
(b) Student grades from previous mathematics classes provided the baseline information for the student mathematics skills. All the grades were in letters and included algebra I and II, algebra II honors, geometry, and geometry honors depending on which classes were taken by the student. Based on the demographics of the grades, first class which has lower grades than the other was assigned as the Online-Tools class, the second class with higher grades assigned as No-Tool class.

VoiceThread Comments. Some of the in-class problems and their solution process were presented to students in the VoiceThreads. Student comments on the VoiceThread slides were a data source to analyze student interaction with the content and the teacher, and used one of the sources to capture student participation in the process of using online tools (See Figure 3.23). Similar to records of student participation in Google Documents, the records of student participation in VoiceThreads was also used for a triangulation component with student self-report from the interviews about the impact of using online technologies on their learning; which informed research question 2.

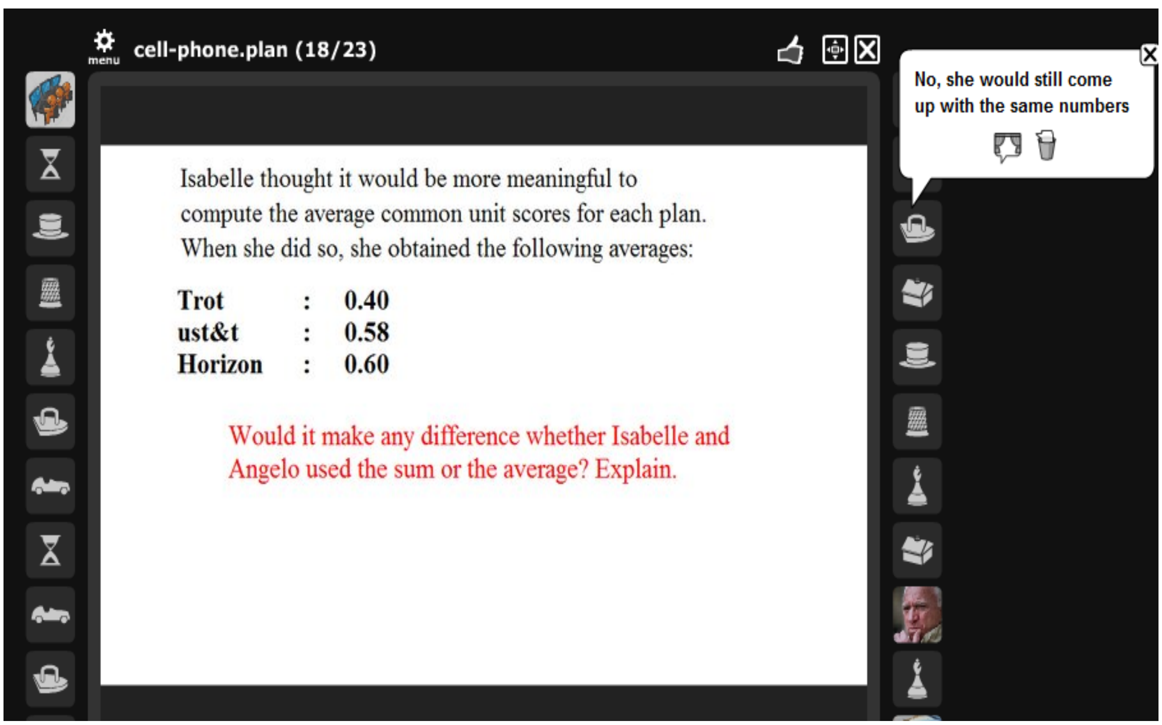


Figure 3.23. Student comments on VoiceThread.

Data Analysis

Glesne (1999) claims that data analysis “involves organizing what you have seen, heard and read so that you can make sense of what you have learned” (p.130). In this process of *making sense of what I have learned*, a researcher needs to categorize, synthesize, search for patterns, and interpret the data collected. The ultimate goal of all this categorizing, synthesizing, and interpreting is to answer the research questions (Merriam, 2009). In this section, the methods that were used to analyze the attitude questionnaire are examined first, which was the only quantitative component of this study; then the methods that were used to analyze the qualitative data are examined, which represents the majority of the data collected in this study.

Quantitative Analysis.

The Mathematics and Technology Attitude Scale responses were analyzed for the students who completed both the pre- and post-survey with 20 items (Appendix H). The size of the sample was 75. The survey responses analyzed with block design in SAS to test: *Is the (Post Mean –Pre Mean) score significantly different from 0.* Teachers were assigned as the random factors. Online-Tools and No-Tool classes assigned as the treatment. The same tests have been completed for the whole scale and for each of the subscales. The estimations were done for the type3 and the REML methods. There was no significant difference between Online-Tools and No-Tool classes for the pre- and post-survey, and no teacher effect was found for the whole scale. The only response variables that showed significant difference were the affective engagement [AE] (with a Kenward Rogers Approximation for the degrees of freedom) and attitude to learning mathematics with technology [MT] subscales. A full explanation of the results of the analyses, along with means and standard deviations; and related box plots and graphs can be found in Chapter Four that addresses the third and fourth research questions.

Qualitative Analysis.

As suggested by Merriam (2009) the researcher started with rudimentary analysis of the data during the data collection, even before the data collection was completed. Before starting the field work, based on the purpose and the research questions of this study, the researcher planned to use a theoretical framework, which was explained in detail in Chapter 2, to analyze the data to answer the first research question. The concepts in the first and second theoretical frameworks, Stahl (2006) and Anderson (2008)'s models, were used as the categories to display the findings for the first question. For the third and fourth research questions Bandura's theories, especially Self-Efficacy Theory; and reviewed literature were used as the starting point for the categories for the analysis of the interview data. Before organizing the data under the categories suggested by the frameworks and the researcher developed a coding and displaying process for the analysis.

Coding. Some strategies were used for early organization of the data during the data collection include: (a) writing a daily memo and keeping reflective field logs to capture the researcher's thoughts when they occur; (b) developing analytic files for each piece of data collected, like quotation files; (c) and developing rudimentary coding schemes by writing down the main points from the data into logs (Glesne, 1999). Then the researcher started code mining to determine the themes and patterns. This code mining process is defined as "process of sorting and defining and defining and sorting those scraps of collected data (i.e., observation notes, interview transcripts, memos, documents, and notes from the relevant literature)" (Glesne, 1999, p.135).

The researcher followed the following steps simultaneously to code the data that was collected through the observations, student interviews, teacher interviews, and teacher reflections: (a) the category construction, (b) sorting categories and data, (c) and naming the categories (Merriam, 2009).

a) The category construction. Since the focus of this study was students, the researcher started coding student interviews, then the categories that emerged to organize the information from the other sources were used of the data. In addition new categories that were not available from the student interviews, but emerged from the other data sources were included. All the coding of the student interviews were done in an excel spreadsheet. Not all of the interviews were transcribed; instead the researcher listened to the interview recordings and wrote down what the student said under a category that was created y the researcher. For the interviews that were transcribed, the researcher listened to the interview recordings to make the codes more accurate or in case anything was missed in the transcript; then the researcher copied and pasted what the student said under a category. Below is the explanation of how the categories are named under the *naming the categories* section.

At the beginning of the coding, the researcher was trying to identify any possible segment of data that might be related to the questions. All different sets of data from different sources were merged in the same single spreadsheet and organized them based on the research questions to determine the *recurring regularities* or *patterns* for the study; which were named as *categories* or *themes* by Merriam, 2009. The researcher listened to the first interview and recorded every part of the interview that seemed related to the study under a category (even non-related parts to have a picture of how a future study might be conducted); which was defined as *open coding* by Merriam (2009). Mostly the researcher wrote down exactly what the student said to be able to make direct quotations throughout the writing of the findings, but also took notes about the interpretations. When the first interview was finished, the researcher continued with other interviews. For each interview, the researcher first checked the categories available from the previous interviews; then created other categories that were emerging from the current interview that were not available from the previous interviews. The same procedures were followed for teacher interviews, teacher reflections, and the observation notes to catch any other possible findings to answer the research questions.

b) *Sorting Categories and Data.* There are questions in the interview protocol that were meant to answer different research questions. The structure of the questions helped the researcher to decide the main categories in the coding, but it was also needed to create a lot of subcategories. When the researcher was satisfied with the main categories, she continued to check for evidence for the categories that were created from different pieces of the data. Sometimes students made comments related to another research question in her/his response to the particular question asked. When that occurred, other categories were created based on student answers. Sometimes the researcher decided to make a category a subcategory; or merged categories or subcategories with one another. These sorting of both categories and data continued through the coding of all pieces of data. All the sorting and organizing were done in an excel spreadsheet for the student interviews. For the teacher interviews and the teacher reflections, each teacher completed two reflections, were coded following a similar process with the student interviews after the completion of the student interviews' coding. This data was not included in the spreadsheet, since it was much smaller than the student interview data.

Naming the Categories. The names of the categories in the coding came from three core sources: (a) using the researcher's own words to name a category; (b) participants, using an exact word or phrase that was used directly by participants; (c) sources from outside, including theoretical frameworks and schemes developed by Stahl (2006) and Anderson (1994) (first research question) and Bandura's terms (third and fourth research questions). Sometimes the researcher checked the literature to name the categories with the words that were used in previous studies, if they explained well what was meant by that category.

Displaying. After all the data were coded and entered, the researcher started organizing the documents that were provided by the teacher, which were all student grades through the semester. All student grades were organized in one single excel spread sheet with eight pages. The researcher created two pages for each class: one page for their grades during my study and one page for their grades before/ after the study throughout the semester, then calculated averages of the grades on each page for each individual student. Those average grades were used as one of the data pieces demonstrating the impact of using online tools on student learning (Research question 2). To evaluate the impact of using online tools on student learning accurately, student participation for the VoiceThread and Google Document assignments were counted; then this information entered and displayed -- student average grades during and before/after the study, and student perceptions gleaned through the interviews -- into one big table which was used while answering research question 2.

Data Saturation.

Bogdan and Biklen (2007) argue that qualitative researchers do not predetermine time limits for data collection. Instead they collect data until the information from the data sources becomes redundant. To be able to realize that point, which is called *data saturation*, the researcher needs to have well-defined goals. In this stduy study, the researcher used the theoretical framework explained above to define the expected emerging themes, so that each data piece could be analyze as soon as it was collected. It was checked if the reported common headings and themes given in the framework could also be seen from the data of this study. Then the researcher made a list of themes that emerged from the data. The researcher collected data until getting a sense that the participants' general learning outcomes and attitude development were understood and until it was possible to provide evidence for those understandings from the data. In other words, the researcher decided that adequate data was collected, if each of the research questions were answered based on the data. For example there were positive, negative, and moderate attitudes among participants towards

VoiceThread and Google Documents. The researcher merged the data again and again until she decided that the themes that emerged started to repeat.

Yin (2003) suggests strategies to increase the quality of a case study as: (a) converging evidence from multiple data sources converging on the same set of facts and findings, (b) developing a case study database to present the assembly of evidence, and (c) developing a chain of evidence between the questions asked, the data collected, and the conclusions drawn. These were among the strategies that were used to decide if the collected data was enough.

Research Validity and Reliability

Glesne (1999) defines term validity as trustworthiness of a qualitative study. Three major aspects of trustworthiness of a study were presented as internal validity, reliability, and external validity (generalizability) by Merriam (1995). *Internal validity* refers to how congruent one's findings are with reality. It is important to remember that reality is constructed, multidimensional, and dynamic from the qualitative perspective, and the researcher offers her interpretation of someone else's interpretation of reality. *Reliability* deals with the issue of the extent to which one's findings will be found again, "the extent to which results are consistent over time and an accurate representation of the total population under study" (Joppe, 2000, p.1). In qualitative research, reliability is not about replication of measures or inquiry; instead, the intention of the qualitative researcher is to understand the world from the perspectives of those in it (Merriam, 1995). *External validity*, in general, refers to the extent to which the findings of a study can be applied to other situations

(Merriam, 1995). There are different approaches among qualitative researchers for the term external validity (or generalizability).They will be explained later.

Merriam (1995) suggests triangulation, member checks, a statement of the researcher's subjectivity, and engagement in the research situation as the strategies that can be applied to increase the internal validity of a qualitative study. In this study, for triangulation, data were collected from students, teachers, and written or electronic documents. To collect data from those multiple sources, the researcher applied multiple data collection methods. Persistent observations, which are defined as extending time in the field by Glesne (1999), was the first data collection strategy used in my study. The researcher were in the classes for every class session during my study to understand the general school and classroom environment, student relations with each other and with their teacher, and students' computer skills and confidence.

Merriam (1995) argues that most qualitative researchers interpret generalization more different than generalizing from sample to population, since the aim of qualitative research is to understand the particular in depth rather than seeking for general truths. The truth is also defined as relative and changeable in qualitative manner. Three different conceptualizations of generalization are given by Merriam (1995), among others. In the first approach, generalizations are situation-specific working hypotheses that reflect situation-specific local conditions of a particular context. It is important to provide details about the particular well enough to the reader. Second, generalizations are concrete universals, which indicate each generalization comes from particular situations that have similar conditions. So we make generalizations using our knowledge for conditions about cumulative particulars. The third approach suggests reader or user generalization. According to this approach, it is not the researcher's responsibility to make generalization, because the reader determines if the findings from the particular are useful or applicable to another situation.

From another point of view, Miles and Huberman (1994) present the idea of generalization as a connection making. Three levels of generalization were given as: sample to population, theory connected, and case-to-case transfer. The first one is not applicable to qualitative research; instead, theory connections or case-to-case transfers can be made using some strategies. For theory connections, it is important to determine if the findings are congruent with or connected to prior theory, if the transferable theory was made explicit enough, or if a general cross-case theory using the sequences has been developed. For case-to-case transfers, it is important to think about the limitations of the study, and if they were discussed in detail, if the report of a study suggests settings where the findings could be tested further, or if the findings have been replicated to assess their robustness.

Limitations to Data Collection

Curriculum Limitations.

The particular curriculum, MINDSET, was chosen for its unique structure which is appropriate for the purposes of this study. However, that particular structure also brought some limitations. The content of some of the chapters of this curriculum is quite different from other chapters. Those differences make some particular chapters more appropriate for using the online tools, VoiceThread and Google Documents. For example, the particular chapters chosen for this study require more collaboration, since the assessment of those chapters was amiable to assessing group projects. This was not true for all of the chapters. This situation limited the chapters that students used Google Documents for group work.

Technology Limitations.

The limited accessibility of computers in the school was another limitation of the data collection for this study. The teacher notified me that she could only use the computer lab for two days a week at most. This situation limited the data collection about students' use of online tools during the instruction. So the computer lab sessions were used to train students about the online tools, and the rest of the students' use of online tools were asynchronous and the data were collected from the documents of that asynchronous collaboration.

Time Limitation.

One of the limitations for data collection was the needed time to prepare VoiceThreads. Since the content of the chapters are relatively different from each other, Ithe researcher needed to prepare separate VoiceThreads for each chapter. So, like the data collection with Google Documents, data collection was limited to particular chapters. Similarly, data collection through VoiceThreads was also limited to particular chapters of the MINDSET curriculum.

Participant Limitation.

This study was planned for a specific curriculum, so this situation limited the site and sample selection of the study, and decreased the number of teachers who might have participated. Teacher contribution was crucial for the purposes of this study, so the study was done only with volunteer teachers. Only two teachers have volunteered to participate in this study, so data are available only for the classes of those two teachers. Student participation was also limited by the number of students who did complete the consent form.

Summary

This study was completed with four high school classes with two teachers. Each teacher had two classes. One of their classes was assigned as the Online-Tools class that had access to VoiceThreads and Google Documents, and the other class was assigned as the No-Tool class that was not introduced any online technologies. The data for this multiple case study were collected through classroom observations, student and teacher interviews, document analysis, teacher reflections, and an attitude questionnaire administered to students. The detailed description of the design of this study, participants, settings, procedures, materials and tools, instruments, data collection and analysis processes are included in this chapter above. Lastly, the research validity and reliability; and limitations to data collection for this study are presented. The findings of this study for each research question are presented in the following chapter (Chapter 4).

CHAPTER 4: FINDINGS

The goal of this study was to investigate student-student interaction, communication, and collaboration that developed with the support of online technologies and their impacts on student learning and attitude in a blended, authentic mathematics curriculum at the high school level. Two mathematics teachers and ninety high school students participated in this study. Two classes of Teacher A were Advance Functions and Modeling (AFM) classes and two classes of Teacher B were Discrete Mathematics classes (see Chapter 3 for more information about AFM and discrete mathematics). One of the classes of each teacher was assigned as Online-Tools class and the other as the No-Tool class (Figure 4.1).

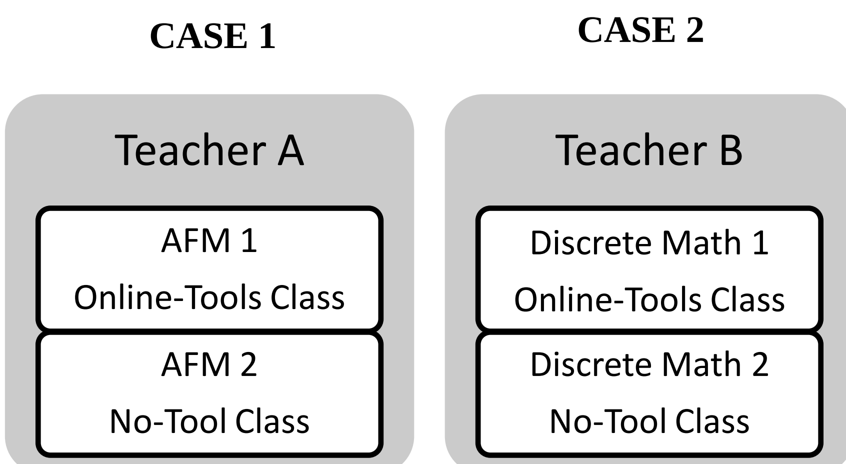


Figure 4.1. Definitions of Case 1 and Case 2.

Findings from the interviews with students, and teachers; from the attitude questionnaire, and from researchers’ observations and document analysis are provided in this section to answer the four research questions. This section provides the results and conclusions for each research question.

Research Question 1

How do student-student interaction, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum?

The diagram explaining the structure of knowledge building in a CSCL environment, which was developed by Stahl (2006) in Figure 4.2; and a model of online learning, which was generated by Anderson (2008) in Figure 4.3, are used to analyze student-student interaction, communication and collaboration using online tools in this study.

Interactions situated in Stahl's model.

As explained in detail in Chapter 2, Stahl’s model was chosen as the first framework for this study. Stahl’s studies are mostly at the K-12 level, so it is an appropriate model for this study that is on high school level. One of the purposes in choosing Stahl’s model was to see which steps of social knowledge building, suggested by Stahl, are being supported by the online tools and the curriculum that was chosen for this study. In this regard each concept in Stahl’s model is used as a category for the analysis to answer the first research question below. Under each category, it is explained if that component was revealed by the data in this study or not, what interpretations and conclusions can be made from the data about that specific component. Since the results about personal understanding were answering the second research question of this study as well; the findings about personal understanding are also presented for the second research question; but only some findings about personal understanding are presented here to make connections with the findings of this study and Stahl's framework as a whole.

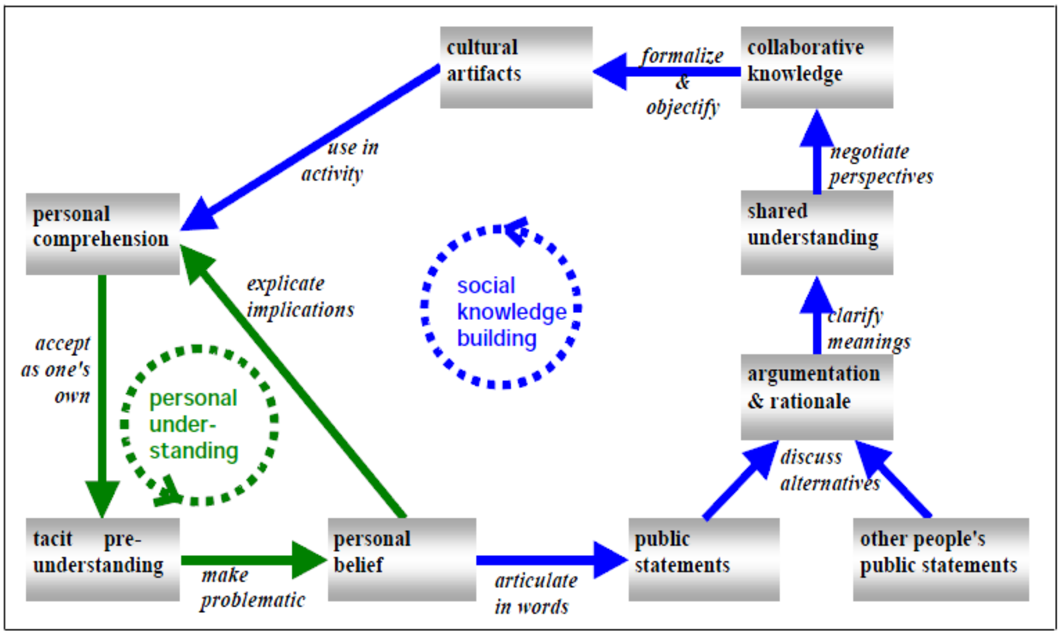


Figure 4. 2. A diagram of knowledge-building processes. "Group cognition: computer support for building collaborative knowledge," by G. Stahl, 2006, *Cambridge, MA: MIT Press*, p. 203. Copyright 2006 by Massachusetts Institute of Technology.

Stahl (2006) stated that *personal understanding* and *social knowledge building* can only be separated artificially, and his model in Figure 4.2 attempts to demonstrate the mutual constitution of these two concepts. The arrows in the diagram represent transformative processes and the rectangles represent the products of these processes. The representation of the diagram is limited in many ways; since individual cognitive processes, collaborative group processes, and mutual relationships among them are complex and fluid phenomena (Stahl, 2006). For example, even if the process seems sequential from an examination of the diagram; interactions among the many components can make the process more complex. Thus this model was used only as a starting point to explain student-student communication, collaboration and interactions. Then, the findings about some additional interactions are presented based on Anderson (2008)'s model. Finally, all the findings are discussed and a modified model is suggested in chapter 5 combining Stahl and Anderson's models. Below, the findings of this study related to Stahl's model are presented through an examination of the student interviews and researcher observations.

Personal understanding.

Individual understanding is one of the two units of analysis in Stahl's model and in Computer Supported Collaborative Learning (CSCL) in general. In earlier studies, learning was acknowledged as being central to the individual process, while CSCL research values the importance of both group processes and individual processes as the two units of analysis for the analysis of learning in groups (Stahl, Koschmann, and Suthers, 2006). According to Singh (2009), studying collaborative knowledge building requires comprehensive units of analysis that allow the researcher not only to focus on the processes that emerge in the group work; but also to focus on each individual in the groups because of the nature of the tools used at the individual and group level. To examine student-student interaction, communication, and collaboration in this study; the interview questions that were asked to students were not only about the group work, but also their individual understanding due to its direct relations with collaborative knowledge building process. At the same time the findings about students' personal understanding are used to answer the second research question, which was about the impacts of online tools on student learning. In this case most of the findings about the personal understanding are presented for the second research questions. Only some of the findings are presented here, since they demonstrate how well students' work in this study aligned with the theoretical models of this study and existing literature.

In this study to investigate the personal understanding process with the help of online tools, the following interview question was asked to student in the Online-Tools classes: "Did you find using VoiceThread and Google Documents helpful to learn the content in this class?" Twenty three students out of thirty five answered this question saying "yes" with positive comments, while eight students reported negative perceptions, and three students had neutral perceptions about using online tools in their math class. Some of the exemplar student comments are presented in detail below with their relation to students' personal understanding.

Students who had positive comments about the VoiceThread emphasized that to practice in-class problems through the VoiceThreads increased their personal comprehension. For example; Student TA3, an Online-Tool Class student with positive perceptions about VoiceThread, when asked how VoiceThread helped him to learn better revealed his usage of VoiceThread as a practice tool for his personal comprehension: "I can go back learn it by my own. It is helpful to be able to go back…..I can practice it as many times as I need going back through the VoiceThread." This idea is supported by Karpicke and Roediger III (2008): "A basic tenet of human learning and memory research is that repetition of material improves its retention" (p. 968). In this regard Student TA8 stated the importance of repetition for his personal understanding: "I always like the fact that when teachers give you things you have done, just being able to go back to it. Even if you have the answers, it is nice to rework problems. You really stick them in your mind." He explains how practicing problems that the teacher already solved in-class, helped him to strengthen his personal understanding parallel to the general tenet given by Karpicke and Roediger III (2008). Student TA 10 also mentioned how those practices helped in the retention of the material in the exam: "Just giving me examples to realize the stuff on the test that I could remember the time I went on the VoiceThread, and did…look at those and answer the question, it was similar to the test question. So it helped me on the test." She was talking about the questions that were asked students during the VoiceThread presentations. She mentioned that the questions in the VoiceThread presentations were similar to questions on the test, which helped her to remember some information.

According to Donald Schön (1983) (as cited in Stahl, 2006), the starting point of our learning is our tacit pre-understanding. However, there could be problematic parts in our understanding. We may solve those problems and reach new levels of comprehension through the interaction with the world; like using tools and symbolic representations (Stahl, 2006). Student TB5 indicated a valuable feature of the VoiceThread as being a vehicle to move from tacit pre-understanding to a new comprehension by clarifying concepts: "I used it

(VoiceThread) for a Google Document assignment. I could not remember the difference between Kruskal and Dijkstra's algorithm, which was which, how to do it. I did go back VoiceThread for that." Similar to student TB5, student TA25 stated how VoiceThread helped him to bridge the gaps in his learning: "I like stuff like that (VoiceThread) in addition to the class. That is helpful; because it is like: if I do not understand something in class, then I can go back to that (VoiceThread)." He had the pre- understanding of the content from the face-to-face class and visited the VoiceThread to settle that understanding in his mind and move to a new comprehension.

Students also mentioned that sometimes their learning through the group work helped to strengthen their personal comprehension. For example, sometimes what they have learned from their partner during Google Document assignments increased their personal comprehension and strengthened their personal beliefs. Those student comments related to group work and how group work helped for their personal understanding are included in the following section.

Social knowledge building 1: Public statements. Stahl argues that it is not always possible to solve the problems in tacit pre-understanding internally. In that case, individuals may enter into a social process and the group of people build new meanings collaboratively. During this process individuals express their initial beliefs in words through their public statements, which help individuals to enter into an interaction, communication, and collaboration process. There were two forms of public statements made by students in this study: (1) Public statements on the VoiceThread slides, (2) Public statements during the Google Document assignments. These two types of public statements are analyzed below:

For the VoiceThread assignments, students were required to answer some questions on specific slides by leaving a text comment on the slide. Those student comments were visible only to the teacher and the researcher at first, and then after the due date those student statements were opened to the public. This assignment encouraged students to explicate their understanding of the content. Stahl argues that the cycle of social knowledge building starts when someone's belief is articulated in words; and the personal understanding cycle in the diagram; including personal comprehension, tacit pre-understanding, and personal belief; can be involved at social phases. In her comment below, student TA25 is explaining why she finds others' public statements in the VoiceThread helpful:

> *StudentTA25:* I like that you view other people's questions and comments they put on it (VoiceThread). So that you can see like how other people kind of communicate with teacher.
>
> *Researcher:* So, you like to see how other class members look through the content and what they say about it?
>
> *StudentTA25:* Yes, like different perspectives.

In her comment below, Student TA20 explains how another student's question on VoiceThread helped her to clarify the concept:

> *Researcher:* What about the option that you have to comment on a slide and ask the teacher a question? Do you like this option?

> *Student TA20:* Yeah I think I like it. All of a sudden I understand… like common value... One person asked about common value and she (the teacher) responded to it.

For the Google Document assignments, students worked in groups of two or three. Students were required to discuss the solution steps to the problem explicitly in the document, but they skipped this stage or preferred to use the chat panel for their communications. So, their communications were not explicit in the Google Document itself. The possible reasons for using chat for communication and not participating in the Google Document are presented later in this chapter. For some problems; instead of negotiating and discussing alternatives, individuals in the group continued working on the solution process at the point where other group members left. Students' contributions to the solution process are named as their public statements here. During the analysis of the student participation in the Google Documents; sometimes both students' public statements were observed in the Google Document, but sometimes only one person's public statement was observed (especially for Teacher B's Online-Tool class). Thus, some students only had their own solution in the document. So those students could not have a chance to take advantage of collaboration on their personal understanding; but for the groups in which each individual actively participated in the solution process and had positive comments about their group work, it helped to develop their personal comprehension. For example, StudentTA6 explains how her group members helped her to understand a specific problem:

> I think using Google Documents helped me to learn the content better, because then with the Google Documents, since you are working with other people; maybe they

understand better than you and they can explain it to you more. Last night there was something I did not understand. So I asked my partner who was also working on the document about how to do it. She explained it to me… I like working with others. So yes, I found it helpful.

Even if StudentTA6 was talking about her partner's statements, it was not explicit in the Google Document; since we can understand that they did their negotiations and discussions in the chat panel on the side. Student TA25's response to the question below gives an idea about why students completed transformative processes; like discussing alternatives, clarifying meanings, negotiating perspectives; through the chat panel:

Question: Why do you think people prefer using chat instead of using the actual document?

Student TA25: I think it is because to kind of make sure what they are doing is right. Like if you chat about it first, and then all of you make sure that it is right, and then you go to the actual document instead of initially going there without having that.

According to Stahl individuals have their personal beliefs and those beliefs generate the socio-cultural knowledge through communication, argumentation, discussion, clarification and negotiation. The communication could develop on various forms: "propositional content, perspective-taking, social interaction, repair of misunderstandings, latent connotations, etc." (Stahl, 2006, p. 6). Next section below presents which ones of those communication and collaboration processes occurred and how they developed during this study.

Social knowledge building 2: Argumentation & rationale, shared understanding, collaborative knowledge building. As explained above, the analysis of student contributions in the Google Document assignments revealed that the following transformative processes were not explicit in the Google Documents during students' group work: discussing alternatives, clarifying meanings, negotiating perspectives. Since the discussing alternatives stage was missing, the product of that process, which was argumentation and rationale, did not occur in the Google Documents during the social knowledge building process by students. Even if the transformative processes were not explicit in the Google Documents, some students completed those steps in the chat panel and developed their *shared understanding* and *collaborative knowledge* after their clarifications and negotiations with each other through the chat panel as indicated in the comments below:

> *Student TA10:* I like working with groups. I like working at the little chat thing that we could ask questions to each other, because sometimes our teacher was not available. It was really convenient having a person, your partner, to type and chat with
>
> *Student TB1:* Usually a lot of people, they cannot meet up and do it together so it is easy for you to go on there (Google Documents) and it will save for you and they can go on there and they can check it and change whatever they want so it is easy."

For some students, it was enough to see what has been done by other group members. They did not need to negotiate or discuss other's solutions, just continued to the solution from where others left:

> *Student TA6:* Yes, it (using Google Documents) was really helpful... I mean we do not use it (Google Document) actually to talk to each other, but it was good to see what work has been done. When your group likes that, you are just trying to go from where others left."

From the analysis of the Google Documents and from the student interviews the researcher concluded that for some problems, the *collaborative knowledge* stage occurred as *cooperative knowledge* instead of collaborative. The reasons for this are discussed in Chapter 5, but below are some student comments supporting this idea. For example Student TA16 was explaining how they divided the solution of the mini project of Chapters 2 and 3 in parts between each other and completed it cooperatively:

> *Researcher:* (When I visit your group's Google Document) I saw that only one group member visited the document several times.
>
> *Student TA16:* Yes, he got the problem part and tonight my other partner will set up the excel sheet and I will run the solver and make the problems.

Student TA3 was explaining his group's work for the same project with a similar comment:

> *Student TA3:* We sit next to each other in class. So we kind of worked out who is going to do what.

Researcher: So you divided the tasks in small parts when you are in class, face-to-face? *Student TA3:* Right.

Researcher: Did you try to communicate with your partner through the Google Document?

Student TA3: Not really. We just talked in class, it is just easier.

From the student comments above, we can understand that students preferred to communicate face-to-face to divide the solution process among each other, and everyone completed their own part; which means they worked cooperatively to complete the problem. The concepts of collaborative and cooperative knowledge building; and their relations with the other concepts in the social-knowledge building process are discussed in chapter 5.

Other interactions situated in Anderson's model.

Although, Stahl's model was chosen as the first framework to answer the first research question; during the data collection and analysis process, the researcher decided to use Anderson's model as the second framework; since: (a) Some of the steps suggested by Stahl did not occur in this study for various reasons and (b) Stahl's model did not cover all types of interactions that were observed during this study. At first glance, it seems that Stahl's model fits better for the analysis of this study, since the focus of this study was the student-student interaction, communication, and collaboration. However, it did not explain the other components of the whole interaction processes which had an unavoidable impact on the development of student-student interaction. So, the researcher decided to add the second theory, an online learning theory that was developed by Anderson (2008) (see Figure 4.3), into the theoretical framework to answer the first research question. Not all components in Anderson's model were used to answer the first research question. The teacher-content, teacher-teacher, content-content interactions are not included in this section; since direct influences of those concepts on student-student interactions were not observed explicitly.

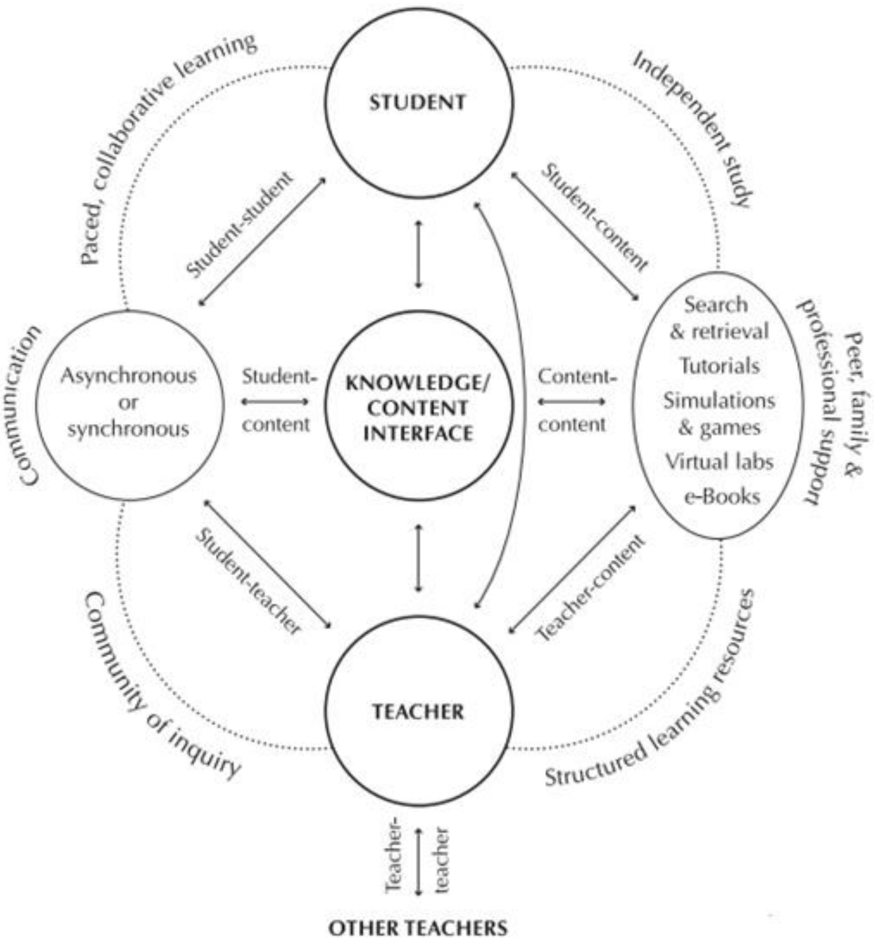


Figure 4. 3. A model of online learning showing types of interaction. Adapted from "Towards a Theory of Online Learning" by T. Anderson, 2008, *In T. Anderson, T. (Eds.), Theory and Practice of Online Learning.* (pp. 45-75), Edmonton, AB, p. 61. Copyright 2008 by Athabasca University, AU Press.

Anderson (2008)'s model is used especially to analyze student-content and student-teacher interactions that were explicitly observed in this study and have direct relationships with student-student interactions. The data provided detailed information about those two components of Anderson's model. For example, students reported their interaction with teacher or content among the influential factors on their learning and/ or attitude. Another component of Anderson's model is student-student interaction. It is also not included in this section, since it was analyzed in detail above with Stahl's model.

Student-content interaction. Anderson defines student-content interaction as a major component in face-to-face and online instruction. He suggests that in an online environment this interaction is more passive than reading textbooks in face-to-face instruction, but it offers some unique opportunities that are not possible in face-to-face form. The analysis of the data revealed that using online tools in blended form made the passive structure of student-content interaction more active by asking questions to students while they are practicing in this study through the VoiceThread presentations. It offers students a platform where they can be more involved in the problem solution process. However this feature was not beneficial for every student. Presentation of a problem slide by slide through the VoiceThread can be confusing for some students. Below are different examples for this situation. For example, Student TA21 was explaining why he prefers VoiceThread to practice problems, instead of textbook:

> *Researcher:* Can you tell me what the difference is between practicing a problem with VoiceThread and with a book?

> *Student TA21:* A book kind of explains it and then gives you problems. VoiceThread kind of stops and asks you questions as it is explaining it. It is a little easier reading and answering questions while you are reading it than answer questions at the end. (late interview, 2:56)

Similar to Student TA21, Student TA15 was telling that he prefers VoiceThread, since it was more engaging for him:

> *Student TA15:* As you go in to the book, a lot of people find it boring; but if you use the VoiceThread it allows you to work in it and see the process by yourself. If you do not understand, you can repeat it as many times as you want. I think it is helpful actually.

Student TA14 does not agree with her peers. She was explaining why she prefers textbook instead of VoiceThread presentation to practice a problem with her comments below:

> *Researcher:* Please talk about your experience with VoiceThread in this class. Did you find using it helpful to learn the content in this class? Why/ Why not?
>
> *Student TA14:* It was, but sometimes it was difficult using it; because it goes forward and you are still reading and trying to understand what is going on in the problem. I did not find it really useful…It did not help me as much as I thought it would.
>
> *Researcher:* Let me ask this: Would you prefer a VoiceThread or your book to practice a problem?
>
> *Student TA14:* I think I really prefer to use my book. VoiceThread is a little complicated, and I am not very good at technology.

Researcher: So can I say you did not like the step by step presentation in the VoiceThread, instead you prefer your book's presentation?

Student TA14: Yes just like having it all there.

Student comments on the VoiceThread were also used in the face-to-face sessions by the teachers (see Figure 4.4); especially to correct misunderstandings and to make clarifications about the problem solution. That uses of VoiceThread in face-to-face provided an extra platform for student-content interaction blending student work on the online presentations with the face-to-face teacher instruction.

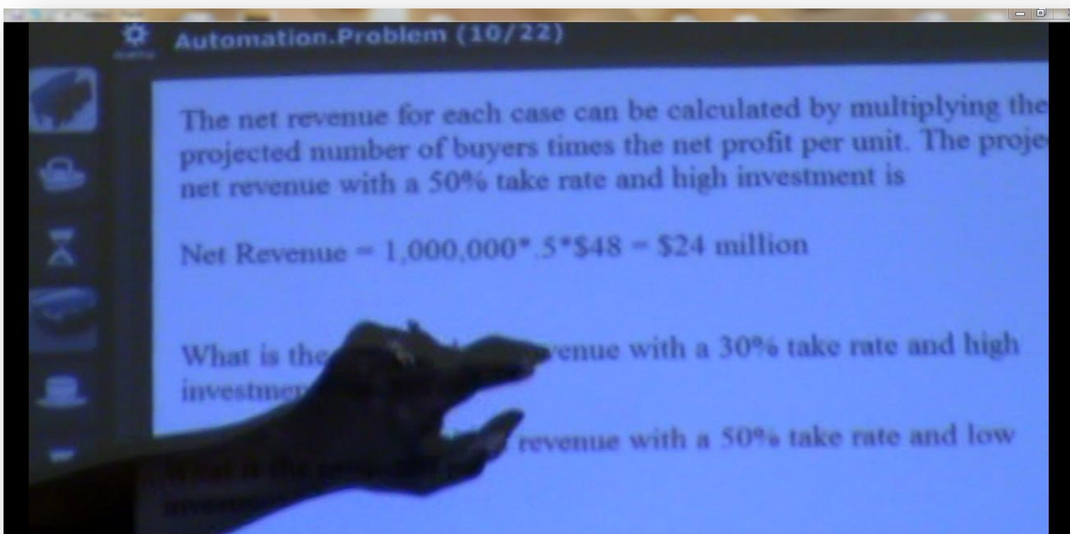


Figure 4.4. Use of Voice Thread comments in face-to-face sessions. Voice Thread comments were visited by teachers in face-to-face sessions to make explanations and to correct misunderstandings, especially before the tests.

All those interactions that occurred between students and the content through the VoiceThreads, and using the VoiceThread in face-to-face sessions fit in the *professional support* component of the Anderson's model where VoiceThread presentations were used like tutorials by students. Those interactive tutorials also provided students an *asynchronous communication* platform with their teacher and peers through the comments that they left on the VoiceThread slides. Bringing VoiceThread comments into face-to-face session enhanced students' interactions with the content by providing them the opportunity to revisit their understanding and correct the problems in their personal beliefs. Teachers reviewed VoiceThread comments especially before the exams and quizzes; so it was reinforcement for students as well.

Student-teacher interaction. In this study, mostly asynchronous, text-based communication occurred between students and teacher in addition to their face-to-face interaction. The analysis revealed that many students appreciated and found beneficial the additional communication opportunities with their teacher, while some students had really high expectations in terms of immediate responses from their teacher.

Student TA15 and Student TA3 are explaining why they found it helpful having the option to communicate with their teacher through the VoiceThread addition to face-to-face interaction.

> *Student TA15:* I do find it helpful and I would use it, if I did not understand a problem. I would just comment to the teacher. When you are in class, she is just

trying you help everybody. But when you are at home, she can go through the VoiceThread and see your comment and reply to it.

Student TA3: Yes, that (VoiceThread) is definitely helpful. I do not feel pleasure to ask questions in class because of this.

Student TA5 was explaining his expectations in terms of immediate response from the teacher and why he prefers to communicate with the teacher face-to-face. According to his comments below, he did not find the teacher response to questions in VoiceThread adequate. However, even if the teacher gives timely feedback and responds to his questions immediately; he would prefer to communicate face-to-face.

Student TA5: Even if you ask questions, she is not going to answer it. So far I haven't seen much response from her.

Researcher: So you prefer more communication with your teacher, if you use the VoiceThread.

Student TA5: Yes. I have learned more through asking questions than she has actually taught us.

Researcher: Do you think it would be better, if you could get more feedback about your answers to the questions?

Student TA5: It could be effective, but she cannot be in front of the computer 24/7.

Researcher: So you prefer having more face-to-face communication and faster responses from your teacher?

Student TA5: Yes, because if you ask a question one day, and you get a response on the next day. You may not even remember what you have asked, but when you asked it face-to face… you give a proper response. I can correlate it to the answer.

The interactions among teacher and students that observed in this study fit in the *asynchronous communication* component of the Anderson's model. The student comments above presents that some students perceive having that asynchronous communication opportunity with the teacher very helpful; while some of them provides more face-to-face and/or synchronous communication with the teacher; especially to get immediate answers to their questions through the learning process.

Many students mentioned that they have used the chat panel for discussions and to clarify questions in their mind. The detailed analysis are included in the section below to look for: (a) the reasons that were given by students for using the chat panel instead of the actual Google Document for discussions and negotiations during the solution process, and (b) the other purposes for which students used the chat panel.

Using Chat & Not Participating in the Google Document.

In this section, two concepts about student–student interaction, communication and collaboration, which were not considered at the beginning of this study, are presented. It drew the researcher's attention that during the implementation a lot of students communicated through the chat panel instead of the Google Document itself; and some students did not participate to the Google Document assignments as expected even through the chat panel. So, student interviews were extended accordingly to investigate these concepts, using chat and not participating in the Google Document, in depth. Below, the findings about these two concepts are presented:

Using Chat. *Using chat* refers to the occurrence of student discussion, negotiation, and clarifications on the chat panel. At the planning stage of this study, it was proposed that students would complete all their communication and discussion in the Google Document itself in the text form. However, even in the training sessions that students had in the schools' computer lab, they discovered the chat panel on the side and completed most of their communication on the chat panel instead of the actual document. Thus, an extension was made to the interview questions and it was asked students for which reasons they used chat instead of the Google Document itself for communication. Below, the reasons that were reported by students for using chat panel for communication are presented:

Actual document seems more formal. One of the common reasons given by students for using chat was that they see the Google Document itself as a formal document where they present the outcome of their work, while the chat is an informal platform where they can make all the clarifications, discussions and negotiations about the problem solution. They did not want to "mess up" their document with the back and forth communications. Instead, they did all communication in the chat panel on the side. For example, when Student TA10 was asked why she and her group used chat, she said: "I guess because the document seems more 'documenting it' … formal. The chat seems easier to...Like the document seemed more permanent, but the chat seemed more temporary." When Student TB15 was asked what they usually discussed with her partners in the chat, she explained how they used chat for clarification about their solution in the chat like this: “If I was having an issue doing the actual problem, I told my partner I did it multiple times, I could not get it, letting him know that I would keep trying. For another one I asked my partner to check what I did.”

For Student TA21 and his group, the chat panel was a place where they divided the solution process into small parts, and then each person completed their part and shared it in the Google Document with others. He said: “We were communicating through the document by making graphs and stuff like that before we found the chat. When we found the chat we would then say you find the information on this and I will find the information on that. And then we would put the information into a chart.” Additionally, Student TA6 explained the difference between the languages they used in the document and in the chat like this: “I think we all more used to chatting, because we were talking about that it was like a *math facebook*…the one on the document, we were trying to type everything right, but we were chatting we were just using a slang kind of everybody understands”.

Chat is faster. When Student TA8 was asked how they communicated for their Google Document assignments, he explained the whole communication process for his group like this:

Student TA8: We have found that there is the chat box on the side, we just used that.

Researcher: Why do you think you preferred to chat instead of writing on the actual document?

Student TA8: It is slower, If you typing in the document. Chat is instant.

> *Researcher:* For which purposes did you use the chat, what was your discussion in chat? *Student TA8:* We talked about what we need to do, who was taking care of what, just everything about the project. This was nice… It is faster. There would be delay in her computer and mine when we write in the actual document itself. And it is possibly mess up the actual document, you can accidently delete something or so. So writing in the chat just keeps it simple.

Similarly Student TB21 mentioned how using the Google Document itself was slowing down the communication process in her comment about using chat: "Using chat was better because we were both working at the same time, I could tell him or her immediately. But if I save the document I have to text him or her, tell them to go back and fix it. It would take more time. It was easier for us to communicate."

Convenient and neater communication. A lot of student reported that they found communicating through the chat more convenient than typing into the Google Document itself. For example, Student TA20 said: I liked chat better because it is faster and it is like on like separate part so it is not like confusing when I am looking at it. With a similar comment, more in detail Student TA9 said that:

> I liked that Google Documents have the chat pane on the side, so if my partner was somewhere else I can still chat with him, and it would be like we were talking. So that helped us about who is going to do what in the paper. That was helpful. If that chat was not there, we have been totally lost. Everyone would have been typing all over the place. It would have been a mess.

For Student TA 10, the chat panel was the place where she could clarify information with her partners, when the teacher was not there: "I like working with groups. I like working at the little chat thing that we could ask questions to each other, because sometimes Miss Dixon was not available. It was really convenient having a person, your partner, to type and chat with."

Similarly, Student TA 14 "Sometimes it does not show up as fast, if you do not use the chat… When I was working with my partner, she was typing on the document and it did not show up on the same place in mine."

Not participating in the Google Document. Some students preferred neither collaborating with their partner through the Google Document nor communicating via chat panel. So another extension to my interview questions was asking the students who did not participate in the Google Documents the reasons for that. Figure 4.5 below presents the percentage of group participations for the each Google Document assignment for both cases.

The reasons that were reported by students for not participating in the Google Document assignments are presented below to help the reader understanding the findings of this study:

New concept. Interestingly, when Student TA4 was asked about why he did not participate in Google Document assignments, he mentioned that: using communication and collaboration tools and talk about his understanding was hard for him in mathematics; since he has never done it before. He said:

With computer it is kind of hard to transfer mathematics doing everything and typing it up I am not used doing it in math class. It is kind of weird for me, because we are typing and explaining stuff. I am just used to having a text book and a work book having paper and doing the problems by hand with the calculator.

CASE 1	% of Groups No one signed in	% of Groups Only one partner worked	% of Groups More than one partners worked	**CASE 2**	% of Groups No one signed in	% of Groups Only one partner worked	% of Groups More than one partners worked
Google Assignments				**Google Assignments**			
Chapter 1 (FinalProject)	0	0	100	Chapter 9 (Kevin Bacon Game)	0	42	58
Chapters 2&3 (Mini Project)	8	23	69	Chapter9 (Homework 9.5.3)	25	42	33
Chapter 11 (Restaurant Problem)	15	23	62	Chapter 9 (Homework 9.5.4)	17	58	25
Chapter 11 (Wayne State Products)	0	31	69	Chapter 10 (Homework 10.5.2)	8	67	25
				Chapter 10 (Homework 10.5.3)	17	58	25
				Chapter 10 (CPM Project)	12.5	37.5	50
				Chapter19- (Homework 3)	18	64	18

Figure 4.5. Percentages of student participations in the Google Document assignments.

Relationship with the partner. Another interesting student comment was from Student TA2 who reported his negative previous experience with his Google assignment partner as a reason for not participating in the Google Document. When asked: “Do you think this kind of communication tool (Google Document) was helpful?” He said:

> I think it just depends on who your partner is. My partner is …Me and him do not get along. Back in middle school we had fights and everything. I normally do it all (Google). Google Documents actually pretty helpful… I just think this particular one (assignment with Google Document) was not good, because I did not have a good partner.

Other classes and homework. When they were asked the reason for them for not participating in the Google Document assignments, Student TA1 said that: “I have not had time. I am taking chemistry and other hard classes.” And Student TA2 said: “It is more about other classes, too. I missed a few days of the school. I have been trying to make up a couple tests and some homework I have been missing.”

Procrastination. Since it takes a longer time than face-to-face instant communication, students should have started working on the Google assignments earlier to give time for their partner to communicate back and make progress in the problem solution collaboratively. Teacher A explains this process with her comment below when she was talking about student communication and collaboration process using the Google Documents:

> I think when you are in a Google Document; you have to wait for someone to respond, that slows down the process. I also think that they (students) procrastinated

with it. They wait until the last minute or the day before or the day off. And then, they do not have the time to collaborate via the document. If you are going to communicate or collaborate using the documents; you have to give people time to respond to what you have done; but if you wait until last minute you cannot do that. You have to meet face-to-face and actually collaborate like that.

However, most of the students are used to work on their assignments really close to the due date which prevented them from using Google Documents effectively. Student TA9 and Student TA25 were agreeing with that and they said:

Student TA9: The reason I did not get to it so late, I am just procrastinating everything to the last moment. I am not sure about my partner.

Student TA25: Mine is just...I do not work on it a little bite, and I procrastinate. I do not think I really have to do something about the document. As soon as I sign in, I do it. It is not because of the document, it is my procrastination.

Preference of synchronous communication. When Student TA16 was asked why only one group member visited the document several times, but he and the other partner did not participate; he said:

Student TA16: Yes, he got the problem part, I guess, and tonight my other partner will set up the excel (sheet) and I will run the solver and make the problems.

Researcher: So you preferred to communicate with each other in class instead of using the document?

Student TA16: Kind of… I thought I would be using it more, but it ended up like that we just talked about it in class…if we ended up being on it at the same time then we used it to communicate, other than that we just talked about everything in class.

The section below presents the teachers perceptions about the student interaction, communication, and collaboration that developed with the help of online tools in this study.

Teacher Perceptions.

Teachers were asked the interview question below related to the first research question:

Can you talk about using VoiceThread and Google Documents to teach this class? Did these online tools help students to interact, communicate, and collaborate with you and with each other? Why/ Why not?

Teachers' comments are consistent with student comments as explained in detail above in terms of not having a lot of interactions among students through the Google Documents, but more of face-to-face interactions. Teacher B interestingly suggested that being assigned as partners for the Google Document assignments facilitated students' face-to face interaction with their group members. Teacher A also suggested that VoiceThread could be used as a more effective communication tool between her and her students with more timely feedback.

Teacher A explained her observations about student communication and collaboration through the online tools like this:

> I do not think that I did do a good job with that for communicating back and forth. Yes they (students) have answered the questions, but I did not do as much in terms of commenting back to them; using that as a way communicate back to them on the VoiceThread. We did use the VoiceThread to go on in and answer the questions, like a sensitivity report. So I communicated in that way by going over the VoiceThread questions, but not me communicating with students within VoiceThread. In terms of the Google Document, I think, on the MAUT (chapter1) project where they (students) were doing their projects, and they were putting the information. I do not think that they have collaborated as much as we would have liked them to do in the document. I think they were communicating, but maybe more face-to-face. So they decide: 'Ok you do this, this, and this part and I will do A, B, and C parts' So, they decided that face-to-face, and then each person worked on that. For example, on the second project, in which we had max and min problems, there were some groups that wrote out their problems by hand and the other person actually input it into the Google Document. So…We could not see a lot of collaboration on the Google Document.

When the second interview question was asked to Teacher B she said: "I definitely like the idea between the VoiceThread and the Google Docs but I just feel like um the students didn't really use the tools for their full ability to interact with one another and communicate with one another." She also talked about how Google Document assignments facilitated students' face-to-face interaction with each other:

> I think the biggest thing would be the online collaboration forcing face to face collaboration. Especially with the students who don't do as well for one reason or another be it due to absences causing them to miss a lot of material causing them to not do as well in the class or just not being as strong a math student as others they wouldn't necessarily feel comfortable asking other people questions, but since that's their partner and they have to do their homework together they kind of have to ask them questions…It was really neat to see them (students) come into school the next day "saying I don't know how to do this, can you help me" to their partner. So they did do some face to face collaboration because of their partner assignments but it wasn't strictly online. They wouldn't necessarily have asked that to some of those people oh how you did this can you help me with this to that particular person because normally they would have done their homework and moved on.

Summary

Findings of this study represented a detailed analysis of the interaction, communication, and collaboration processes using online tools in blended form. Unexpectedly, students completed most of their communications through the chat panel instead of the actual document during the Google Document assignments. The negotiations, discussions, and clarifications among students mostly took place in the chat panel as well. For some problems students skipped those discussion steps, and completed the problem solution cooperatively (cooperative student work it will be discussed in detail in Chapter 5). The interactions observed not only among the students; but also student-content and student-teacher interaction were observed. The findings suggest that student-content and student-teacher interaction have direct effects on student-students interaction; so they should be part of the social knowledge building process in the theoretical model; will be discussed in detail in Chapter 5. Students did not communicate as much with their teacher and peers through the VoiceThread comments; but their comments were used in the face-to-face classes for clarifications and reinforcement, especially before the exams. Most of the students appreciated the extra communication opportunities with their teacher, while some students preferred face-to-face communication instead. The findings revealed that student interaction, communication and collaboration have mutual effects with personal understanding. Some of those effects were explained above to demonstrate the connections of the findings with the theoretical models; but they are presented in the findings for second research question below in more detail.

Research Question 2

> How does interaction, communication, and collaboration via online tools impact student learning of an authentic mathematics curriculum?

To investigate the impact of using online tools for interaction, communication, and collaboration on student learning: (a) interviews were conducted with students; and (b) each participants' test, project, and quiz grades were collected and used as a second data source to triangulate with interview data. Teachers were also interviewed and wrote reflections after each chapter about their perceptions of their students' learning. Teacher interviews and reflections were analyzed as a third source of data to examine teachers' perception about student learning. Below the findings from those multiple data sources are provided under three categories: (1) the change in student grades throughout the semester under the *student outcomes* section; (2) student perceptions about the impacts of using online tools on their learning based on the student interviews under the *student perceptions* section; and (3) teacher perceptions about the impacts of using online tools on student learning based on the teacher interviews and reflections under the *teacher perceptions* section.

Student Outcomes.

This study was conducted during the spring 2011 semester. All student grades were collected throughout the semester for each individual student. Case 1 represents the Online-Tools and No-Tool classes of Teacher A and Case 2 represents the Online-Tools and No-Tool classes of Teacher B.

Case 1.Case 1 included Chapters 1, 2, 3 and 11 (implementation chapters); and students took four tests, one quiz, and completed two projects for those chapters. All test, quiz, and project grades for those four chapters were averaged. They are presented in Table 4.1 and pictured in Figure 4.6 below. The grades for the chapters other than the four implementation chapters (other chapters) were also averaged and appear in Table 4.2 and Figure 4.7 below.

Table 4. 1

Average grades of Case1 classes for each implementation chapter.

Implementation Chapters	MAUT-Project	Ch2-Test	Ch3-Test	Max&Min-Project	DecTree-Quiz	Formative 1	Midterm	SD	M
Online-Tools	90.22	86.13	81.88	93.15	89.69	89.36	71.68	7.26	86.01
No-Tool	98.88	83.42	82.59	88.67	91.38	84.54	69.54	9.05	85.57
difference	-8.66	2.71	-0.72	4.49	-1.70	4.82	2.14		0.44

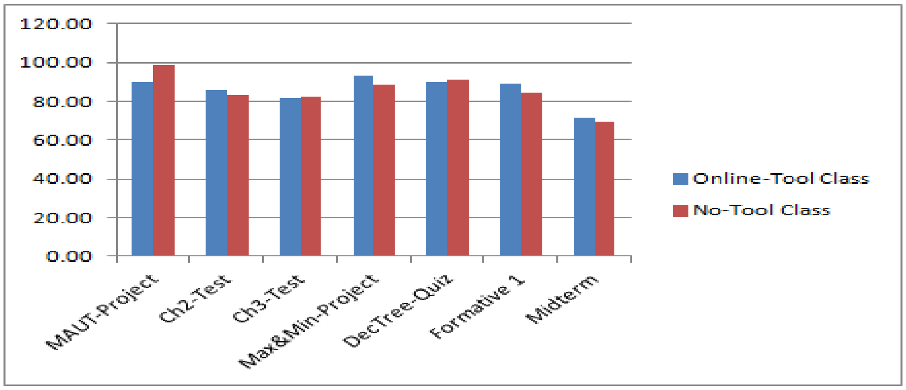


Figure 4. 6. Average grades of Case 1 classes for each implementation chapter.

Table 4. 2

Average grades for Online-Tools and No-Tool classes of Case 1 for each chapter other than the four implementation chapters

Other Chapters	Test1	Test2	Test3	Final	Quiz2	Quiz3	SD	M
Online-Tools	67.46	92.92	88.6	79.95	90.55	89.45	9.58	84.82
No-Tool	66.33	90.26	86.87	80.39	93.95	92.62	10.38	85.07
difference	1.13	2.66	1.73	-0.44	-3.40	-3.17		-0.25

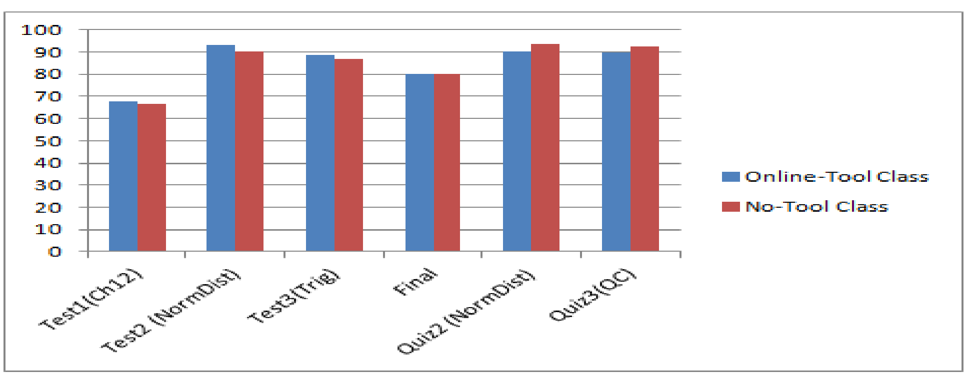


Figure 4. 7. Average grades of Case 1 classes for each chapter other than the four implementation chapters.

According to Table 4.1, for Case 1, for four out of seven implementation chapters, the Online-Tools class had higher average grade than the No-Tool class; and for the other three chapters it was visa versa. For the other chapters, from Table 4.2, for three out of the six chapters Online-Tools class had higher average grade than the No-Tool class; for the other three chapters the No-Tool class had a higher average grade than the Online-Tools class. Combining Table 4.1 and Table 4.2, the percentage of the number of chapters that the Online-Tools class had a higher average grade than the No-Tool class is higher for the implementation chapters than the other chapters. However, the difference between the overall means for two classes is not very large. To make a more accurate conclusion about the difference between average student grades for Online-Tools and No-Tool classes throughout the semester for Case 1, the overall means for implementation and other chapters for both Online-Tools and No-Tool classes are presented in Table 4.3 below. The specific differences among the implementation chapters and possible reasons for those differences will be discussed in Chapter 5.

Table 4. 3

Average class grades and standard deviations for Case 1.

CASE 1	Other chapters	Implementation chapters
Online-Tools Class	84.82 ± 9.58	86.01 ± 7.26
No-Tool Class	85.07 ± 10.38	85.57 ± 9.05

According to Table 4.3, both Online-Tools and No-Tool classes had higher average grade for implementation chapters than the other chapters; while the difference between the implementation and other chapters is higher for Online-Tools class. The improvement in averages class grade for the Online-Tool class implies a positive effect from the use of online tools for problem solving. On the other hand, there is an improvement in average class grade for the No-Tool class as well, which implies that other factors also could be influencing the improvement of student grades for Online-Tools class addition to the technology that they used. But, still the improvement for the Online-Tools class seems higher than the No-Tool class which implies a larger technology effect than effects from other factors. The results for Case 2 and the qualitative findings are provided later in this document as well for more accurate conclusions about the impacts of online tools on student learning. For a more inclusive analysis at the individual level, the differences in individual students' grades are presented below to see if they are parallel to the difference in grades for classes.

Individual students' grades for Case 1.

The overall changes in student grades throughout the semester for each class have been presented above. In this section, the individual student's grades are presented in Table 4.4 for the implementation and the other chapters for Case 1.

Table 4. 4

Average student grades and standard deviations for Case 1 throughout the semester

Online-Tools Class									
	Implementation chapters		Other chapters			Implementation chapters		Other chapters	
Student	M	SD	M	SD	Student	M	SD	M	SD
TA1	70.50	16.05	91.50	8.29	TA15	91.50	3.27	74.17	16.87
TA2	93.83	3.92	87.33	9.50	TA16	80.43	21.07	79.80	12.83
TA3	91.83	6.37	95.80	4.82	TA17	84.17	12.89	71.00	11.38
TA4	91.33	6.95	87.00	13.49	TA18	88.00	11.58	85.83	17.43
TA5	77.43	12.59	84.92	10.60	TA19	90.40	3.58	88.33	16.13
TA6	87.17	17.49	85.40	13.01	TA20	88.00	10.86	86.50	8.78
TA7	80.00	14.63	86.83	12.22	TA21	91.17	5.64	83.25	18.46
TA8	87.67	7.84	89.00	10.84	TA22	86.67	12.36	89.50	15.39
TA9	82.60	14.64	88.40	7.70	TA23	81.17	14.47	80.20	26.80
TA10	76.17	13.54	77.17	10.89	TA25	82.00	8.72	89.25	10.44
TA12	84.83	8.89	74.67	17.78	TA26	87.29	8.04	83.20	5.72
TA13	93.00	4.60	85.17	13.38	TA27	87.83	8.30	92.17	7.08
TA14	76.17	14.58	80.80	14.04					
No-Tool Class									
	Implementation chapters		Other chapters			Implementation chapters		Other chapters	
Student	M	SD	M	SD	Student	M	SD	M	SD
CA1	86.50	11.62	81.67	8.07	CA17	81.57	10.72	69.67	24.93
CA3	87.43	7.91	83.67	19.21	CA18	76.67	18.78	75.17	12.24
CA4	92.57	7.35	94.67	10.48	CA19	79.60	22.03	84.33	17.04
CA5	92.83	4.88	89.80	11.10	CA20	92.00	6.42	47.33	4.47
CA7	87.33	15.77	84.00	15.64	CA21	77.71	16.35	97.00	14.76
CA9	96.17	5.78	35.00	5.03	CA22	88.29	17.39	79.50	5.28
CA10	78.33	22.29	95.67	10.41	CA23	92.00	8.00	95.50	6.27
CA11	78.00	19.48	83.50	14.04	CA24	78.33	18.45	91.83	15.97
CA12	84.33	11.66	82.80	11.95	CA25	91.14	10.75	83.75	11.01
CA13	81.14	14.81	87.00	15.76	CA27	90.50	10.65	89.80	8.08
CA14	87.50	9.05	85.33	8.73	CA28	86.86	9.92	91.17	14.17
CA16	72.00	27.25	91.60	20.67	CA29	82.86	13.21	82.33	19.28

It is obvious from Table 4.4 that the change in grades varies a lot for individual students for the implementation chapters and other chapters; and it is not the same as the change in the average of the whole class for some of the students. From Table 4.4, 56% (14 students) of the Case 1 Online-Tools class had a higher average grade for the implementation chapters than their average grade for other chapters; while 44% (11 students) of Case 1 Online-Tools class had a higher average grade during other chapters than their average grade for implementation chapters.

For the No-Tool class, 48% (12 students) of students had a higher average grade for the implementation chapters than their average grade for other chapters; while 52% (13 students) of them had a higher average grade during other chapters than their average grade for implementation chapters. In addition, as seen in the Table 4.4, differences between average grades for implementation and other chapters were really high for some students such as Student CA24 and not too high for some of the others for instance Student TA23 and sometimes the change in standard deviations is really high. Thus, it is not possible to draw one concrete conclusion about the impact of online tools on student learning at the individual level in terms of their average grades for Case 1; personal differences appear among students. The results for Case 2 are presented below after the table.

Case 2. Case 2 included chapters 9, 10, and 19 (implementation chapters). Students took two tests, two quizzes, and completed one project for those chapters. All test, quiz and project grades for those four chapters were averaged and demonstrated in Table 4.5 and

Figure 4.8 below. The grades for the chapters other than the four implementation chapters (other chapters) were also averaged and presented in Table 4.6 and Figure 4.11 below.

Table 4. 5

Average grades for Case 2 for each implementation chapter

Implementation Chapters	Ch9-Quiz	Ch9-Test	Ch10-Project	Ch19-Quiz	Ch19-Test	SD	Average
Online-Tool Class	88.65	79.60	94.47	97.50	85.17	7.16	89.08
No-Tool Class	94.50	83.10	95.00	97.05	91.26	5.48	92.18
Difference	-5.85	-3.50	-0.53	0.45	-6.09		-3.10

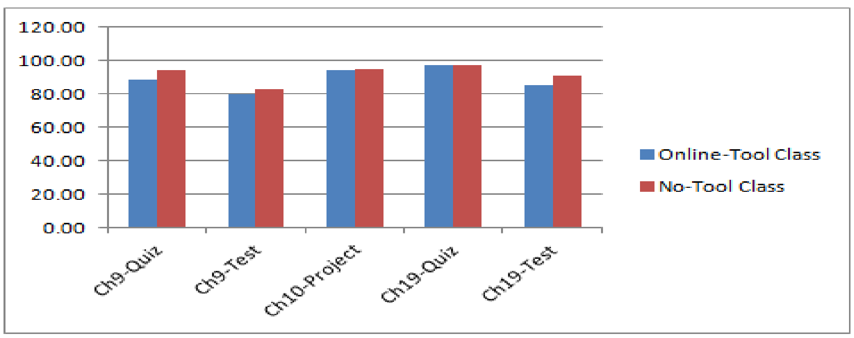


Figure 4.8. Average grades of Case 2 classes for each implementation chapters.

Table 4. 6

Average grades for Case 2 for each chapter other than the three implementation chapters

Other Chapters	Quiz1	Quiz2	Quiz3	Quiz4	Quiz5	Quiz6	Test1	Test2	Test3	Test4	Test5	Test6	Midterm	SD	Mean
Online-Tools	86.59	93.95	91.95	89.50	92.47	92.63	80.28	78.58	82.84	82.40	82.42	83.12	71.40	6.67	85.24
No-Tool	87.79	97.11	88.00	90.25	93.53	99.25	85.47	86.79	80.84	82.50	78.00	82.68	68.90	8.10	86.24
Difference	-1.20	-3.16	3.95	-0.75	-1.06	-6.62	-5.20	-8.21	2.00	-0.10	4.42	0.44	2.50		1.00

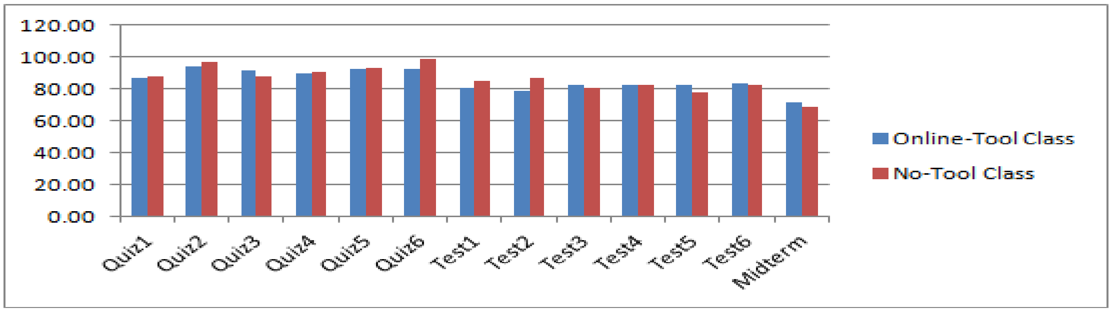


Figure 4.9. Average grades of Case 2 classes for each chapter other than the three implementation chapters.

According to Table 4.5, for Case 2, for one of the tests out of five for the implementation chapters, Online-Tools class had higher average grade than the No-Tool class; and for the other four chapters it was vise versa. For the other chapters, from Table 4.6, for five out of thirteen tests Online-Tools class had higher average grade than the No-Tool class; for the other eight tests No-Tool class had a higher average grade than the Online-Tools class. Combining Table 4.5 and Table 4.6, even if the number of chapters that Online-Tools class had a higher average grade than No-Tool class is lower for the implementation chapters than the other chapters; the differences between the overall means for two classes is high for some chapters and not too high for the others. One reason for these differences can be that the Case 2 classes spent a short time to learn and use the online tools and the time period was at the end of semester. These factors are discussed in detail in Chapter 5. The general differences between the two classes (Online-Tools and No-Tool classes of Case 2) can be another reason for the differences between the implementation and the other chapters for Case 2, the differences between two classes are also discussed in Chapter 5. Similar to the

Case 1, to make more accurate conclusions about the differences between average student grades for Online-Tools and No-Tool classes throughout the semester for Case 2, the overall means for implementation and other chapters for both Online-Tools and No-Tool classes are presented in Table 4.7 below. The specific differences among the chapters and possible reasons for those differences are discussed in Chapter 5.

Table 4. 7

Average class grades and standard deviations for Case 2

CASE 2	**Other chapters**	**implementation chapters**
Online-Tools Class	85.24 ± 6.67	89.08 ± 7.16
No-Tool Class	86.24 ± 8.10	92.18 ± 5.48

Similar to Case 1, Table 4.7 presents a higher average grade for implementation chapters than the other chapters for both the Online-Tools and No-Tool classes. However, in this case, the difference between the implementation and the other chapters is higher for the No-Tool class. Possible reasons for the differences between the Case 1 and Case 2 are discussed in Chapter 5. For the individual level analysis, the differences in individual students' grades throughout the semester are presented later in this document.

Individual students' grades for Case 2. In this section, the individual student's grades are presented in Table 4.8 for the implementation and the other chapters for Case 2. Similar to Case1, the change in grades varies a lot for individual students for the implementation chapters and other chapters; and it is not the same as the change in the average of the whole class for some of the students.

Table 4. 8

Average student grades and standard deviations for Case 2 throughout the semester

Online-Tools Class

	Implementation chapters		Other chapters			Implementation chapters		Other chapters	
Student	M	SD	M	SD	Student	M	SD	M	SD
TB1	85.80	11.56	86.62	11.13	TB13	97.80	2.28	96.46	5.65
TB2	80.40	17.42	74.25	12.08	TB14	92.00	11.38	94.00	7.22
TB3	91.20	7.12	84.92	14.80	TB15	93.20	6.46	89.92	8.25
TB4	87.25	12.26	86.23	8.44	TB16	79.80	20.72	71.92	15.82
TB5	89.40	10.57	89.31	7.76	TB17	97.40	2.51	93.54	7.72
TB6	92.40	9.10	87.92	6.14	TB18	97.80	3.49	95.50	5.66
TB7	75.40	21.79	64.46	16.35	TB19	94.00	6.93	60.46	16.28
TB8	86.40	9.71	85.62	10.43	TB20	85.00	13.21	82.46	12.95
TB11	93.80	6.94	74.31	15.78	TB21	92.60	5.59	88.25	9.74
TB12	90.40	7.92	87.92	12.22	TB22	78.50	5.07	84.85	13.28

No Tool Class

	Implementation chapters		Other chapters			Implementation chapters		Other chapters	
Student	M	SD	M	SD	Student	M	SD	M	SD
CB 2	91.60	9.07	87.08	11.33	CB 17	91.60	11.15	88.92	10.05
CB 3	92.60	7.64	85.62	8.12	CB 18	95.00	6.56	88.85	10.88
CB 6	93.60	6.88	89.23	9.20	CB 19	96.40	2.07	86.00	11.79
CB 7	89.00	17.45	83.54	11.33	CB 22	94.00	9.19	85.46	15.14
CB 8	91.40	10.48	87.46	9.76	CB 23	97.60	2.30	77.45	16.76
CB 10	96.60	3.44	89.92	6.82	CB 24	92.80	10.47	92.85	6.49
CB 11	93.20	8.29	86.31	11.86	CB 25	81.25	13.00	71.38	16.84
CB 12	89.20	8.87	79.46	13.33	CB 26	95.20	5.76	86.69	12.38
CB 15	87.00	4.64	88.85	9.41	CB 27	95.80	4.27	90.57	9.13
CB 16	82.20	5.26	85.77	9.67	CB 28	95.60	4.93	93.08	5.25

From Table 4.8, for Case 2, 80% (16 students) of the Online-Tools class had a higher average grade for the implementation chapters than their average grade for other chapters; while 20% (4 students) of the Case2 Online-Tools class had a higher average grade during other chapters than their average grade for implementation chapters. For No-Tool class, 85% (17 students) in the class had higher an average grade for the implementation chapters than their average grade for other chapters; while 15% (2 students) of the class had a higher average grade during other chapters than their average grade for implementation chapters. In addition, as seen in the Table 4.8, differences between average grades for implementation and other chapters were really high for some students such as Student TB19 and not too high for some of the others for instance Student CB28 and sometimes the change in standard deviations is really high. Thus, it is not possible to draw one concrete conclusion about the impact of online tools on student learning in terms of their average grades for individuals; personal differences appear among students.

In summary, there is a higher average class grade for Online-Tools classes for both Case 1 and Case 2 during the implementation chapters as opposed to the other chapters. That implies a promising positive impact of online technologies on student learning in terms of student grades. On the other hand, there is a higher average grade on the implementation chapters for the No-Tools classes as well, which implies that some other reasons may also be effective on the difference between the implementation and other chapters for both cases. At the same time, there are also some differences between Case 1 and Case 2 in terms of student grades. The possible reasons for the differences between the implementation and other chapters for both cases; and the possible reasons for the differences between Case 1 and Case 2 in terms of student grades are discussed in detail in the discussion chapter (Chapter 5).

The qualitative results regarding the impacts of online tools on student learning are presented in the section below to: (a) triangulate with the quantitative data that were presented above, (b) deeply investigate students' perceptions about the impacts of online tools on their learning and (c) to uncover the reasons for students' positive and negative perceptions about the impact of online tools on their learning.

Student Perceptions of the impacts of online tools on student learning.

To investigate the impacts of online tools on student personal comprehension, the interview questions below were asked to the students in Online-Tools classes of both cases:

(Q5) Please talk about your experience (interaction and communication using) with the VoiceThread in this class. Did you find using it helpful to learn the content in this class (VoiceThread beneficial to practice problems)? Why/ Why not?

(Q8) Did your communication and collaboration with your group members through Google Documents help you to learn content better? Why/ Why not?

Student responses to the interview questions above were analyzed with open coding. The researcher read through or listened the related parts of the interviews and coded student comment as positive, negative or neutral. Figure 4.10 below visualizes these three types of student perceptions with their percentages in one diagram.

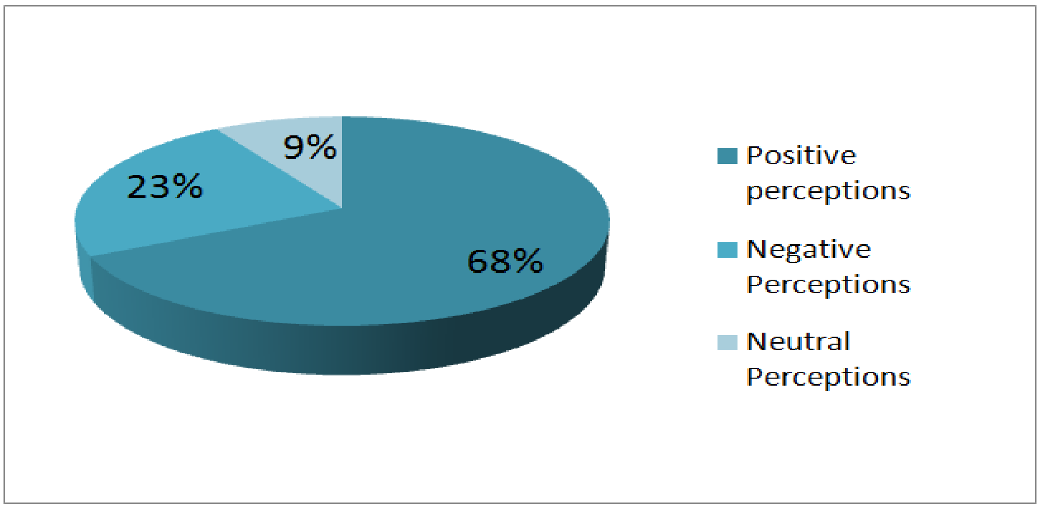


Figure 4.10. Student perceptions with percentages.

Positive Perceptions. Students who used online tools reported various reasons for: Why they think the use of online tools helped them to learn the content better. Eleven themes emerged from the student interviews for positive perceptions. Figure 4.11 provides a quick reference for the major themes that emerged from the interviews with the number of students who mentioned that specific concept, and it represents the basic components of the themes.

THEMES	Basic components	%(out of 35 students)
Good Practice Tool	➢ Dividing the solution process in small parts ➢ Helping to Recall things in the Exam ➢ Easier to go back through the VoiceThread ➢ Step by step explanation	**23**
Clarifying concepts, Reinforcement	➢ Easy to go back and forth ➢ Neater organization to find what you are looking for ➢ Helpful for missed classes	**37**
Multiple Presentation	➢ Visual representation of the information ➢ Different ways to learn math	**11**
Interactivity/	➢ Teacher can see what you did ➢ To able to ask questions while practicing problems ➢ To be able to ask other students questions.	**17**
Multiple perspectives	➢ To be able to see other's interpretations of the problem ➢ To see different approaches to solve the problems	**6**
Working with a partner	➢ Asking help in a group, when teacher is not there ➢ Made communication easier	**29**
Accessibility/ Easier collaboration tool	➢ Having everything in the same document ➢ Automatically save the work ➢ No need to meet up ➢ Helped to plan things	**24**
Helping to put things into practice	➢ Develop their own problems	**6**
Metacognition	➢ Talking to yourself about your learning	**3**
Technology-savvy / neater	➢ Cooler ➢ Neater than the hand writing	**14**

Figure 4.11. Major themes that emerged from the student interviews about positive attitude towards online tools.

Below, some exemplar student comments and explanations for each theme are presented.

Good practice tool. Many students who found VoiceThread a beneficial practice tool mentioned its feature to navigate easily. In this way they could repeat any part of the process several times. Student TA14 compares this easy navigation feature of VoiceThread with face-to-face instruction saying that: “It was easy to use VoiceThread, because you can go back. In a class you cannot do that. So it was easy to go forward and back.” Some students also found helpful how the problem solution was divided into small pieces with the VoiceThread slides. For example, Student TA20 found the presentation in VoiceThread slides beneficial; since she could comprehend the content easier with this way. She says: “I do not focus as much, if it is in the book. It seems you need to comprehend it in one time. On the slides it is shorter and broken down.”

Student TB6 argued the VoiceThread presentation was like a substitute teacher when he was practicing problems at home: “I have liked…you had basically another teacher at the house when your teacher was not there.”

Clarifying concepts, reinforcement. Many students suggested VoiceThread and Google Document as beneficial tools for reinforcement for what they have learned in face-to-face instruction. For example Student TB14 said that:

> It helped me understand it more because we were getting this stuff in class and we would go home and go on VoiceThread and then we would reinforce it because it would be on the presentation and we could just answer questions relevant to the lesson.

Student TA5 claim that he did not learn something new through the assignments that he completed using Google Document with his groups, but it was consolidating his knowledge:

"I would not say I did learn anything from the Google Documents, but it helps us to reinforce what we have already known."

Other students used VoiceThread when they missed, forgot or did not understand something from the face-to-face class:

Student TA25: I like stuff like that (VoiceThread) in addition to the class. That is helpful; because it is like: if I do not understand something in class, then I can go back to that (VoiceThread)."

Student TB21: Yes (VoiceThread was helpful), especially the part where there was a recording. Sometimes I daydream during class so it was helpful to go back and listen again. If I had this for all of my classes I wouldn't come to school actually I would just go and listen online."

Student TB6: Sometimes I go back and look at it (VoiceThread), if I forgot something.

Student TB17 found VoiceThread presentation easier to clarify a concept that he was confused about: "I liked that it ordered stuff. If you needed to see something, you can go back see what ever slide."

Visual (multiple) representation/ different ways to learn math. Some students found online tools beneficial, since they offered multiple ways for presentation and for the solution of the problems. Student TA3 says: "I did find it (VoiceThread) useful, because it gave me more visual representation of the information than I got in class." Student TA15 emphasized the usefulness of using VoiceThread and Google Documents especially for learning mathematics: “I think they (online tools) were helpful when you are learning math, because people learn math in different ways, even if you do the same thing. In this way you can have multiple ways to work on math problems.”

Interactivity/ to able to ask questions while practicing problems. Interaction with the content, with the teacher, and with peers are among the factors reported by students for why they have found VoiceThread and Google Documents beneficial for their learning. For example, Student TA4 was highlighting the interaction with the content through the VoiceThread: “It (VoiceThread) is more interactive. I can control it. It is more like personal interactive.”

Several students mentioned they have found the option to ask the teacher questions helpful when they were practicing. For example Student TA12 says: “Yes, I do actually (find VoiceThread helpful). The teacher can see what you did, and you can ask a question. You can ask a question when you are at home.”Some students also mentioned that asking questions to peers was helpful, Student TA21: “It (communication with peers and teacher through VoiceThread) is a lot easier to learn because you don’t have to wait until the next day to come in and ask a question and you can ask other students.” StudentTA9 emphasized that she especially found helpful that the teacher answered the questions in VoiceThread during the next face-to-face session: “I liked the option to comment…you can ask questions and she can go over it in class. It is very helpful.”

Multiple perspectives. When the researcher asked about why they have found online tools helpful, two students mentioned they found it helpful that they could see each others’ work through the VoiceThread comments and Google Document. Even if they did not specifically explain how having multiple perspectives helped them for their learning, both Student TA2 and Student TA20 emphasized the importance of having access to each others' work and to see different ways for solution. Student TA20 benefited from this feature through the Google Document, while Student TA2 took advantage of the same feature through the VoiceThread comments:

> *Student TA2:* In VoiceThread you could see the other people's responses to compare and like get different ideas of how the problem can be solved and it opens you up a lot of different ways. Where as in class, if the teacher writes the question on board and…you hear only one person's response. This way you can hear multiple voices.
>
> *Student TA20:* "Yeah. It (Google Document) was helpful, doing different problems. You can just go on and see what other people do. In my group when we are doing the project we can all see what each other is writing. So we saw different ways of interpreting the problem, understanding and solving it."

Working with a partner. Many students argued that communicating and collaborating through Google Documents helped them during the problem solution process. Usually they took advantage of discussing the different ways to solve the problem. They learned from each other, and they chose the best solution and put it in the Google Document as the group's solution. According to Student TA12, Google Document was a platform where people can ask for help from other group members when they need: "if I need help on something; someone else may have better idea. I can ask for help and they can help me." Student TA6 explains the collaboration process in the Google Document in detail with another perspective:

> Yes. I think, it (Google Document) is better; because all of you sitting right there and you kind of just do your own thing, but at the same time if they think that is not right they can collaborate that way instead of being face-to-face. So, I think more classes should use Google Documents actually...My math and technology confidence got higher because now I feel more of that it is not just pen and paper, you can go into the Internet and do it, then somebody else is going in and check what you have done, and you can also go back and check what they are doing. So you can see what people do, while they were working and maybe if it doesn't work for you, you can do it another way."

Student TB5's comment below demonstrates that for some groups the Google Document was not a communication or collaboration platform. Instead, one group members completed one part of the solution through the Google Document and the other person used her/ his work to complete another piece with paper and pencil. For those groups who did not actively communicate or collaborate through the Google Document, it was a part of their cooperative work, and having access to the same document made their cooperation easier:

> Yes, I thought it (Google Document) was helpful. With my partner, we did the final project together. She put all the things in the Google Documents, it was really nice. When I was trying to complete the actual diagraph, they all were there for me (the information needed for the diagraph). That was really nice.

Accessibility. Student TA21 was explaining how having access to the same document with his group members helped them to complete their group work like this:

> I thought it was pretty cool; especially that we could have chats with each other about different questions and stuff; and not have to figure out a time to meet. It is definitely helpful. It is a lot easier for us as a group to work on a project than individually because we can all work on the document at the same time, which makes it a lot easier when you are working in groups.

Helping to put things into practice. Student TA10 mentioned how the assignments for which they used Google Documents with her group members to develop their own problems helped her to learn better, instead of only working with paper and pencil:

> It helped to put into practice what I have learned the day she (the teacher) taught it. It helped me to put into practice and apply it. The AFM, it helped me to understand it (math), because my learning style if I just read it on paper and then do problems; it does not really click. But if I actually have put it in a situation where I make up my own problem, it helps me to get to know it better. It is like when you teach something you get to understand it a little bit more.

Metacognition. Interestingly Student TA2 talked about how online tools helped him to think about his own learning. Students had access to each other's solutions through the online tools; and Student TA2 said that in this way he realized others were also making mistakes and starting to question his own learning. Once he settled his knowledge after questioning and comparing with others' knowledge; he felt more confident:

> Using VoiceThread and Google Documents made me more confident. I speak in my mind about what I thought the answer was. If I disagree with someone about a certain thing, I can say 'Oh, I thought it this way'; because everyone else has problems out there too. So it was not like, 'Oh, I am the only one makes a mistake'.

Technology-savvy / Neater- 6

Some students found online tools helpful just because they provided them a more technological way to work on mathematics problems. For Student TA20 working with technology was an alternative to face-to-face lecture, and worked better for her: "It is a lot easier. I understand technology more than just being told something." Similarly Student TA21 was comparing practicing a problem with textbook and with VoiceThread: "It (using VoiceThread) was easier than going through a book or a text."

Negative perceptions. Figure 4.12 provides a quick reference for the major themes that emerged from the student interviews with the number of students who mentioned that specific concept for her/his negative attitude towards the online tools. The themes decided through the reading/listening the related parts of the interviews. First, the initial categories are noted in the excel code book; then some categories combined and the themes below emerged.

THEMES	**%(out of 35 students)**
Preference of synchronous communication/ immediate response to questions	17
Hard to carry a computer	9
Dislike of Computers	3
Unnecessary	6

Figure 4. 12. Major themes that emerged from the student interviews about negative attitude towards online tools.

Preference of synchronous communication/ immediate response to questions. The most reported reason for why students did not find online tools helpful for their learning by them was that: they found face-to-face communication more effective, since they could get more immediate response to their questions. For example Student TA24 said:

> I would more prefer to ask (my questions) in class. I understand more and better, if something is explained in person. If I ask in the VoiceThread and get an answer there, it is not like asking a question in the first place. I mean, in class you kind of get immediate response. If I you have asked your question in VoiceThread and get the answer in class, you might have forgotten your question.

Student TA14 explained, in her comment below, why she prefers to communicate face-to-face with her group members:

> I think it (collaborating through the Google Document) was a little more difficult, because we were not like face-to-face, and we could not get in everything right away. Google Documents is not good for synchronous communication: It was helpful when we were trying find out what is the project on, but it was not helpful when all three of

us trying to talk at the same time. It gets confusing. You do not understand what we are doing, who is doing what.

Hard to carry a computer. A couple of students thought doing homework on a computer was harder than paper-pencil homework. Student TA6 was explaining why she finds paper-pencil homework and using the book for practice more convenient: “I like the book, because it is more accessible I guess. You can carry it around; you cannot carry a computer around.” Student TB17 agreed that doing homework on a computer was harder, but he found the solution by using his phone; since the homework was accessible through the internet: “VoiceThread is sometimes hard to use, because you are not around the computer all the time. I was able to do some of the stuff on my phone.”

Dislike of Computers. Even if many students had positive attitudes towards using more technology in their mathematics class, some students said that they do not like using technology. Student TB5 says “We used them (VoiceThread) last year for English class, I hate computers in general. I just do not like technology.” For some students, it was different. When I asked Student TB11: *Did you like using technology in math?* He said: *No*; but when I asked*: In general, do you like using technology?* He said: *Yes. 2:16*. He did not give any reason for his negative attitude to using technology in mathematics class; but it is interesting he said he likes using technology outside of the class, but he did not like using it for mathematics homework.

Unnecessary. Some students found using online tools for doing homework just unnecessary. For example Student TB8 said: “I felt it (VoiceThread homework) was a little unnecessary. Instead of go online; we could have it on a piece of paper.”

Neutral perceptions. Some students did not have any positive or negative perceptions about the online tools. For example, even if Student TA8 said **“**I do think the technology in this case is very beneficial, especially with this curriculum. They go very nice together”, when I asked him the impact of technology on his learning he said: “I would not say that had an effect. I would not say it had a negative effect. It was just a piece of technology; it was a tool to be able getting our work done.” And, Student TA24 said “There is not really any difference between if I did a work sheet or if I did the VoiceThread. I mean they are the same for me.”

Teacher Perceptions.

Teachers were asked the interview question below to investigate their perceptions about the impacts of online tools on student learning:

> *Question 2:* Did you observe any impacts on students' learning when they used VoiceThread and Google Documents to interact, communicate, and collaborate? (last teacher interview)

Both teachers reported that they perceived VoiceThread more beneficial to students; but they could not observe direct impact of Google Documents on student learning. For example below is Teacher A’s answer to the interview question:

> I think, so far with VoiceThread, I think that in terms of if it is helping to students for further understand the material. It was helpful for that. It reinforced their understanding of the material… and with the Google Documents; they were giving us a finished product. I think the only difference would be that instead of them turning in a sheet of paper that they have written on, they have done everything on the computer. So I do not know if the Google Documents themselves helped the students to learn better, or if I saw any impact on student learning; because to me it is just another way for them to present their work. With the VoiceThread, I think, that lent itself more to improving student understanding than the Google Document.

Interestingly Teacher A mentioned that she had higher expectations for 3rd period, No-Tool class, at the beginning of the semester than 4th period, Online-Tools class; since most of them had a stronger background. However in her comment below, she explained how she was surprised by the result of the first formative assessment:

> I will say this one thing that I would have thought, if I looked on paper. I had more people in third period who were coming from honors level classes. So they were coming from honors Algebra 2. If you look at on paper, that class should have been a stronger class academically, because most of them were coming from an honors level course and had been in honors level courses in the past. What I have found is that using the formative data to access this, the 4th period actually did better on formative data than the 3rd period, which I would have expected the opposite. Most of the

> students in 3rd period were not in honors level class. They were in academic, and some of them struggled in academic. Majority of them had B's, C's, and some D's in academic. I am not sure if it was because we used the technology or not, but it is interesting that class… I think, if I looked at the numbers of failures in formative… There were more failures in 3rd period (No-Tool class) than there were in 4th period (Online-Tools class).

When the researcher told Teacher A: "Maybe even if they seem to not be learning the content, they are spending time on tools, eventually maybe they'll learn", she said:

> The other thing when I think about it: if you are using the technology, you do have to make sure that you understand the content, before you get to the technology; because if you do not understand the content, you would not know what to put in the Google Documents, etc. So I do think that maybe in some ways the technology tools reinforce the concepts that they learn.

Teacher B mostly talked about how online tools facilitated student learning by offering them alternative opportunities to learn from each other, but she also emphasized the obstacles for online tools being more beneficial. When asked about her thoughts concerning the use of VoiceThread in blended form by allowing students to practice problems when they were at home and asking them questions throughout their practice; and then revisiting their VoiceThread comments in face-to-face instruction, she said:

> It does help, I think sometimes students don't… when I say what questions do you have before the test they don't necessarily remember, but if I pull up their comments

> (on VoiceThread slides) it's like "oh yea, I did have a question about that". Or a lot of times we think we did something right but then we see people's answers and we're like "oh I didn't do that right" so they ask a question about how to get it right.

And, when the researcher asked her about her thoughts concerning the impacts of online tools on student learning; she was more skeptical. She exposed her higher expectations in terms of how online tools could have helped, but she reported that she could not observe that much impact for various reasons. She talked about those reasons like this:

> I don't think that it's impossible to see the differences and I think it could be beneficial but with the constraints we had with it being the end of the year, first period -- the class who used the technology -- having lots of absences and tardiness, that with them not using the tools as much for whatever reason, not having the access even though we thought they had access. It would have been really difficult to see a difference and I can't really say that I did (observe any impacts on students' learning).

Summary

The findings of this study shed a light to the impacts of using online tools on students' learning of mathematics. The quantitative results demonstrated that Case 1Online-Tools class benefited from the online tools more than the Case 2 Online-Tools class. The differences between outcomes of the two cases are discussed in Chapter 5. The change in individuals' grades varies a lot from the implementation to the other chapters in both Cases, which implies individual differences among students to benefit from the use of online tools. Even if the quantitative findings were mixed, the qualitative findings revealed that most of the students have positive perceptions about the impacts of online tools on their learning; while some students have negative and neutral perceptions as well. Some of the reasons that were reported by students for their positive perceptions towards the online tools are: being a good practice tool, allowing more interactions, helping to clarify concepts and reinforcement of the material, being more accessible and easier collaboration tool, making collaboration and group work easier, being more technology savvy. Some of the reasons for negative perceptions are: preference of synchronous communication and/or immediate response to questions, dislike of computers in general, and seeing the use of online tools unnecessary. Teachers mostly emphasized their opinions about perceiving the Voice Thread assignments having more positive effects on student learning than the Google Documents, and teacher A was surprised about the positive results on student outcomes. Teacher B talked about how online tools leaded more interaction and opportunities to learn from each other. She also mentioned the obstacles for the Case 2 Online-Tools class, which are discussed in Chapter 5.

Below the findings for the third research question are presented, which is about the impacts of using online tools on student attitudes.

Research Question 3

In what ways are students' emotional, behavioral, and cognitive attitudes affected by using online tools with an authentic mathematics curriculum at the high school level?

To investigate the impacts of using online tools for interaction, communication, and collaboration on student attitudes: (a) Student responses to Mathematics and Technology

Attitude Scale (MTAS) are summarized with box plots for Online-Tools classes (since the sample sizes were so small, statistical tests were not conducted); (b) interviews were conducted with students as a second data source to triangulate with survey data and analyzed with open coding to investigate each individual's attitude in depth, (c) teachers interviews were conducted with teachers at the end of implementation; and teachers completed reflections after each chapter.

Below results from the attitude survey are provided under the *student outcomes* section for the Online-Tools classes (more statistical analysis will be given for the attitude survey for research question four); the results of the analyzes of student interviews about using online tools and the impacts of using online tools on their attitude are demonstrated under the *student perceptions* section; and the results of the analyzes of teacher perceptions about the impacts of using online tools on student attitude based on the teacher interviews and reflections are demonstrated under the *teacher perceptions* section.

Student outcomes.

Case 1. Table 4.9 below demonstrates the results of pre- and post survey for Online-Tools class for Case 1. The results are pictured in the box plots in Figure 4.13.

Table 4. 9

The minimum, maximum, median, and lower and upper quartile values for subscales of MTAS for Case 1 Online-Tools class

CASE 1	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre		BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	5	11	8	6	5		8	8	4	6	4
Q1	11.00	14.00	11.00	10.00	14.00		11.00	13.50	8.00	9.00	10.50
Median	14.5	15	12.5	12	14.5		14	15.5	14.5	12.5	16
Q3	16.25	18.25	16	14	16		16	20	16.25	15.25	16
Max	19	20	19	18	20		20	20	20	20	20

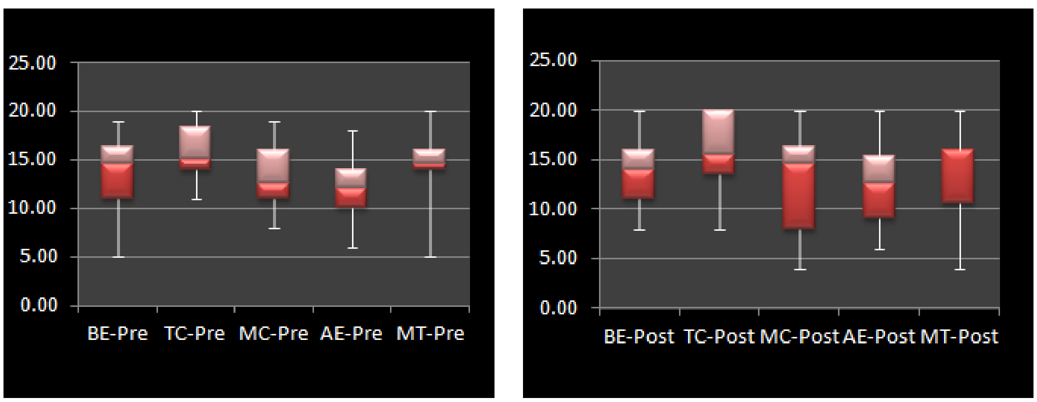


Figure 4.13. Box plots presenting the distribution of MTAS subscale scores for Case 1.

In Table 4.9, a lot of differences are seen between pre- and post-survey results on minimum, maximum, median, upper and lower quartiles. For example, for TC (technology confidence) subscale, the median is 0.5 point higher for the post-survey. That means that 50% of the students score greater than or equal to 15 in the pre-survey; while 50% of the students score greater than or equal to 15.5 in the post-survey. At the same time the upper quartile is 1.75 point higher for the post-survey, which means that 25% of the students score greater than or equal to 18.25 in the pre-survey, while 25% of the students score equal to 20 in the post-survey. On the other hand, the lower quartile is 0.5 point lower for the post-survey; which means 75% of the students score greater than or equal to 14 in the pre-survey, while 75% of the students score equal to 13.5 in the post-survey. The minimum score is 11 for the pre-survey and it is 8 for the post survey; which says some students have lower technology confidence after the implementation. We see similar changes on the other subscales as well. After presentation of the results for the Case 2 below, the change on the mean values are presented for all the subscales along with standard deviations in Table 4.11 for both cases.

Case 2. Table 4.10 below demonstrates the results of pre- and post survey for Online-Tools class for Case 2. The results are pictured in the box plots in Figure 4.14.

Table 4. 10

The minimum, maximum, median, and lower and upper quartile values for subscales of MTAS for Case 2 Online-Tools class

CASE 2	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre		BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	8	9	7	4	9		8	7	4	5	8
Q1	13.5	14	10.5	9	13		12	13	11	11	13
Median	15	15	13	12	14		14	15	14	13	16
Q3	16	15.5	15	14.5	16		16	16	15	16	16
Max	20	19	20	20	19		20	20	20	20	18

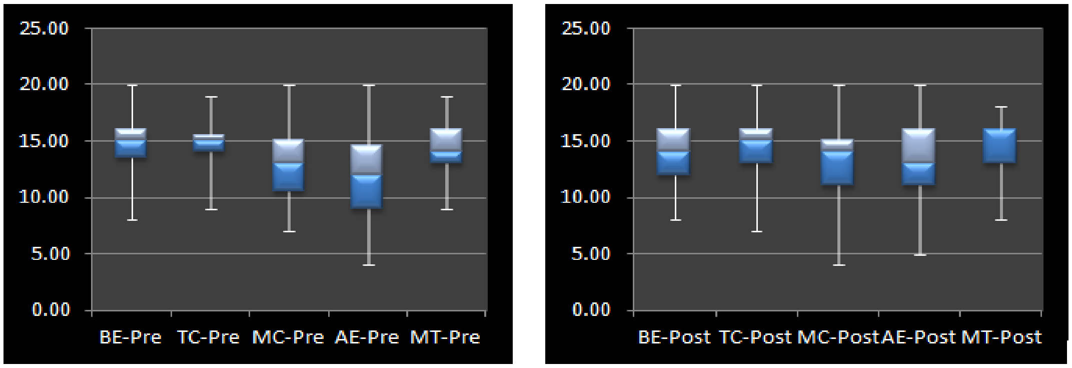


Figure 4.14. Box plots presenting the distribution of MTAS subscale scores for Case 2 Online- Tools class for pre- and post-surveys.

.

Similar to Case 1, in Table 4.10, a lot of differences are seen between pre- and post-survey results on the minimum, the maximum, the median, the upper and the lower quartiles for Case 2. For example, for TC (technology confidence) subscale: The median stays the same which means that 50% of the students score greater than or equal to 15 in both the pre- and post-survey. At the same time the upper quartile is 0.5 point higher for the post-survey, which means: 25% of the students score greater than or equal to 15.5 in the pre-survey, while 25% of the students score equal to 16 in the post-survey. On the other hand, the lower quartile is 1 point lower for the post-survey; which means 75% of the students score greater than or equal to 14 in the pre-survey, while 75% of the students score equal to 13 in the post-survey. The minimum score is 2 point lower, while the maximum score is 1 point greater in the post survey; which says some students had lower and some students had higher technology confidence after the implementation. We see similar changes on the other subscales as well. The changes on the mean values are presented for all the subscales along with standard deviations in Table 4.11 below for both cases.

Combining two cases. Table 4.11 below presents all the mean values for the subscales of the pre- and post-survey. As presented above with the box plots, there were both positive and negative changes in terms of the minimum, the maximum, the median, the upper and the lower quartiles for all the subscales. So, we do not see a big change on the mean value or the change in the standard deviation over shades the positive or the negative change in the mean value.

Table 4. 11

Means and standard deviations of MTAS subscales for pre- and post-survey

CASE 1 (N=19)				**CASE 2 (N=15)**			
Pre- survey		**Post- survey**		**Pre- survey**		**Post- survey**	
BE	13.26±3.71	BE	13.26±3.31	**BE**	14.40±2.92	BE	14.13±3.23
TC	16.05±2.95	TC	16.05±4.03	**TC**	14.40±2.59	TC	14.47±3.23
MC	13.00±3.21	MC	13.32±5.11	**MC**	13.07±3.61	MC	12.80±4.04
AE	11.95±2.74	AE	12.79±4.33	**AE**	12.07±4.11	AE	13.00±3.68
MT	14.68±3.27	MT	14.21±4.74	**MT**	14.20±2.54	MT	14.20±3.21

Subscales**:** Mathematics confidence [MC], confidence with technology [TC], attitude to learning mathematics with technology [MT], affective engagement [AE], and behavioral engagement [BE].

The statistical analyses are presented for the pre- and post-survey combining Case 1 and Case 2 Online-Tools and No-Tool classes together for the fourth research question later in this study. Below student perceptions of the affects of using online tools on their attitude to technology and mathematics are presented based on the student interviews.

Student perceptions of the affects of using online tools on their attitude.

Galbraith and Haines (1998) listed the appropriate measures of attitude where the mathematics and technology (computers in their case) interacts as: the affective domain, mathematics confidence, mathematics motivation, technology confidence, technology motivation, and technology (again computers in their case) and mathematics interaction. The authors define students as having high mathematics motivation; if they challenge themselves to solve mathematical problems and even continue to think about the solution outside of the class. They define students as having high technology motivation; if they find mathematics more enjoyable and enjoy working with computers to solve mathematics problems. And, "students indicating high computer and mathematics interaction believe that computers enhance mathematics learning by the provision of many examples" (p. 278). Based on their definitions, students' technology and mathematics interaction is investigated in the first research question of this study; and the mathematics motivation is not in the scope of this research question. Other than those two measures, findings about different aspects of student attitude towards the technology and mathematics are presented in this section.

Pierce et al. (2007) argue that wording of the statements that were given to students to evaluate their attitude should be appropriate in terms of local culture and context, age, and stage; since student responses will be strongly affected by those factors. The authors argue that students' mathematics attitudes encompass "feelings and opinions about doing and learning mathematics" (p.286) and confidence is an important measure to examine attitude. The Pierce et al.'s definition helped to simplify the wording of the interview questions for high school student for this study while including the measures suggested by Galbraith and Haines (1998). In this regard; to investigate: (a) student attitude towards using online tools in their mathematics class; (b) students' perception about the possible changes in their attitude towards mathematics and technology; and to uncover (c) the reasons for positive and negative student attitudes, students in Online-Tools classes were asked two interview questions below for this study:

> (Q10): Did you like using VoiceThread/ Google Documents for this class? What did you like/ dislike?

> (Q11): Did using VoiceThread and Google Documents make any change on your mathematics and technology confidence, and /your beliefs and feelings about mathematics?

Students had diverse reasons for their positive or negative attitudes to VoiceThread and Google Documents, and using them in their mathematics class. Those reasons and the information about the change on the students' confidence are given in Figure 4.15 below with the number of students who mentioned that specific reason.

Factors affecting attitude towards online tools	**Reasons**	**# of Students**
Communication	Direct communication with teacher **(positive)**	3
	Easy and neat communication and collaboration **(positive)**	2
	Not enough or too much participation by peer **(negative)**	5
	Preference of face-to-face communication **(negative)**	
Effects on learning	Making some tasks easier/ enjoyable **(positive)**	2
	Presentation in small pieces/ less reading **(positive)**	4
	Slowing down some tasks **(negative)**	2
	Preference of hands-on activities **(negative)**	
Time	Time efficient **(positive)**	2
	Time flexibility to do the homework and turn in it **(positive)**	7
Technical factors	Technology savvy **(positive)**	2
	Technical problems **(negative)**	3
	Audio annoying / repetitive **(negative)**	3
	Requiring the internet access **(negative)**	
Other factors	Accessibility **(positive)**	2
	It is a new concept **(negative)**	2
Confidence Level after using online tools	More confident	22
	No change in confidence level	13
	Less Confident	2
	No Comment	3

Figure 4. 15. Emerged major themes about student attitude and change in confidence level.

Below, some exemplar student comments and explanations for each type of student perception about their attitude towards online tools and their confidence level are presented.

Positive Attitude.

Direct communication with teacher. Even if students had face-to-face interaction with the teacher every school day, some students reported that they found it beneficial to have the opportunity to communicate with their teacher through the VoiceThreads. Student TA6 explained how she felt more comfortable asking questions through the VoiceThread, instead of asking in face-to-face class:

> I like that (VoiceThread) better; because then you do not kind of feel apprehensive about asking questions in class and wondering about what other people are saying about the question you have. Even though the class can see your question (in VoiceThread), you are not in the class asking them. You are kind of asking the teacher directly, so I do like that part of that.

Student TA10 found the option of asking questions to the teacher online a contemporary way of communication. She also found the blended form of instruction beneficial, face-to-face instruction and homework through the VoiceThread. She explains these saying: “I liked the fact that we could ask the teacher questions online and she would answer them in the next class. She would not leave me hanging. I found it more up to date and more modern.” Student TA8 also mentioned asking questions through the VoiceThread as being an alternative way to communicate with teacher, and why he found it helpful:

> *Researcher:* What about asking questions option?
>
> *Student TA8:* I liked it, because if you have a question when you are at home you cannot get contact with your teacher. For other classes I just e-mail my teacher and

she/he can get back to me with more technology savvy teachers. This is about the same thing. I do like it a lot.

Presentation in small pieces/ less reading. Some students found the presentation of the problems in VoiceThread helpful; since it was easier to navigate from one piece of information to another while seeking for specific information. For example Student TB17 said: **"**I liked that it (VoiceThread) ordered stuff. If you needed to see something, you can go back see what ever slide." Student TA6 also emphasized she liked the presentation of problems in VoiceThread; since it has less reading: "I liked the computer better, because with a book I get so tired of reading; so the computer is more like…I like stuff like that."

Making some tasks easier/ enjoyable. Student TA21 was explaining his experience in class and how it is easier with online tools like this: "When I first heard about AFM I thought it was harder than that. It was too much fun. It is actually a lot easier to get at home and work on stuff through VoiceThread than book problems." Student TB12 agreed with that doing homework with online tools was easier, since she found typing easier than hand-writing: "You just go in and comment, just answer the questions. I thought it is easy to type things. It is better than hand writing. I enjoy typing." Student TA6 found class more enjoyable and easier using online tools especially because of the drawing feature of Google Document, which students used for Chapter 11: "Drawing in Google, I enjoyed that. It was pretty fun to me…Instead of writing on a piece of paper, it was a lot easier" Student TA10 explains how working in groups and dividing the problem solution between the group members was easier with Google Documents:

> It is more "technology savvy" .It is more my style. It was easier just work together on it rather than work separately and all combine it together. Usually what happens is we work separately and all combine it. One person always has to do the entire poster. I guess it is easier to do equal to each person”

Accessibility. Some students liked the accessibility of Google Documents from anytime and anywhere, and found it convenient while working for their projects. StudentTB5 explain this saying: “What I did like is the fact that it is all there. If I never need it or I forgot my book, I have always my computer at home. I can always check it up and it is always right there.” Student TA9 was agreeing with that, and she also emphasize that she liked how Google Documents automatically save the work and the easy access:

> *Researcher:* You also used Google Documents when you are at home. Did you like using Google Documents when you are at home?
>
> *StudentTA9:* Yes. That way I did not need to save my thing on a flash drive. I am not worried to lose my flash drive. It was nice to not worry about transferring and losing it. It is already there, saved on there. All I have to do is to log into Google and it is right there.

Easy and neat communication and collaboration. Many students reported that they have found using Google Document for communication and collaboration for their group work neater, easier, and cooler. For example, Student TA4 says: “Google… I liked being a part of the same thing, so you can work together... That was a cool thing how you can just do it when you are not together, you can both do it." Student TB21explains why she liked using online tools in mathematics class with these words:

Researcher: Did you like using VoiceThread/ Google Documents for this class?

StudentTB21: Yes, using technology made it (the class) more enjoyable.

Researcher: Is there anything specifically that you can mention you liked or disliked about this?

StudentTB21: I liked the easier way to communicate, neater, more professional, and easy to save… I cannot think of anything I dislike right now.

Time efficient. Student TA10 and Student TA12 especially liked how using Google Documents for group work saved their time:

Student TA10: It (Google Document) was really really cool. I really liked that you can just type on it and the other person can type at the exact the same time, but on another subject about a different part of it. So you do not have to type the exact same thing. It was more time efficient.

Student TA12: Yes (I liked Google Documents), because when we are at home I can ask questions… It makes things faster, and someone else can collaborate with.

Time flexibility to do the homework and turn in it. Another factor reported by students for their positive attitude to using online tools was doing and submitting their homework anytime that is convenient:

Student TA25: I think it (Google Document) is a great idea… You can do all that on your own time, and still collaborate with your group.

> *Student TA8:* I liked the idea the homework on computer, and to be able turning in any time instead of turning in class. I feel it gives you more freedom, because you can do it during school and turn it in anytime.

Technology -savvy. Using more technology was the most reported reason for their positive attitude, some students just like doing things on a computer instead of paper and pencil. For example Student TA6 told that she felt successful and more confident in this class than other math classes. When asked the reason for that, she said: "that could be some of because you are hands-on what you are learning and it is not all text book. Most of the work we do in class involves in some kind of computer or technology which I like."

Student TA8 explained that he liked being able to interact with teacher outside of the class using technology like this: "I liked the interaction…I always love working with technology, I liked even from home to be able to use technology to contact with my teacher."

Student TB1 shared his fears about using Google Documents before using it, and how it helped him to learn math:

> I've never used Google docs and I thought I was going to have a nightmare with it but it was easy to use and it helped with math because I would always go on the computer so I would just bring that up and I could just do it.

And, Student TB14 pointed out some specific tasks that were easier using technology:

> I liked VoiceThread because I didn't have to go through and write it down on paper and it like saved it and we didn't get handouts and we didn't have to write down stuff. We would just use the internet and if we had a problem with it we could just email

> someone about it. I liked Google documents because we could just make shapes fast and easy, like draw lines and stuff, instead of having to sit down and draw something out we could just use pre-set and make charts and graphs.

Negative Attitude.

Preference of face-to-face communication/ Preference of hands-on activities. Students with negative attitudes towards using online tools in their mathematics class are usually comparing using Google Documents with face-to-face communication and collaboration; or doing homework on VoiceThread with using paper and pencil to do homework. Most of them emphasized the advantages of face-to-face communication over using Google Documents. Student TA7 was explaining the situation for her group and why they did not communicate through the Google Document with these words:

> Google…you can understand more from each other in person. It is harder to communicate and show people what you mean (in Google Document)…I just prefer (communicating) face-to-face (Int.2-2:09-2:26)…this is why we planned in class what we are going to do, and who is going to do what, and just each go in and do what she/he needs to do, but we did not talk at all on the Google Documents.

Some students mentioned that it was hard to communicate through the Google Documents, since they had to type everything. They also mentioned sometimes they could not understand each others' opinion well enough by typing and it slows down the communication process. For example, Student TA14 was explaining why it was harder for her to communicate through the Google Document with her comments below:

Student TA14: It was easier to communicate face-to-face. You were able to get everything out right away instead of typing in everything.

Researcher: So typing takes longer time?

Student TA14: Yes, because you ask a question and they answer and then if you have another...it is kind of confusing if you have more than two people in the group.

Some students did not like using online tools, since they did not like asynchronous communication. For example when Student TA21 was asked if he liked communicating online with his group members, he said: “No. It is too confusing. You have to wait for them to reply, takes forever.”

For the VoiceThread, some students also mentioned typing as a disadvantage; since they would prefer hand writing. For instance, Student TA9 said that, “It (VoiceThread) is an Ok way to do it (homework), but I like writing; so I would rather sit there and write it out, but it worked fine for me.”

Technical Problems. During the training sessions in school, sometimes students had technical problems with the VoiceThread; or while opening their Google Documents or using some features of the application. Some of the problems were because of that several people were trying to reach the same server at the same time. However some students reported that they had similar problems when they were using the tools at home to do their homework. For instance, Student TB6 said that: **“**Sometimes I disliked it (using online tools), because I could not log in and I had to go back and log in to my Gmail. It took a little longer.” 8:26. StudentTB5 reported a similar problem with both the Google Documents and the

VoiceThread: "I had a really hard time getting in (to the Google Documents), especially the drawing, it did not work on my computer. It was about my computer or it was about the system, I do not know… Sometimes I had problem getting in (VoiceThread). Sometimes, it is just me I forgot how to get in or I do not remember the password or something."

Not enough or too much participation by peer. As mentioned previously, for some groups only one group member completed the Google Document assignment, so they could not benefit from communicating and collaborating through the Google Document with their partner. Some students mentioned this as a reason for their negative attitude towards using Google Document for group work. For example Student TA10 said that: "I did not like that (using Google Document)... everybody was not participating. I would like to see that everybody participates, because they may have a question that I have thought about and then I forgot.

Student TB20 had an opposite comment about her partner's participation:

> Sometimes, I would have liked it better if it was just me, I felt like I would have gotten more done. Because sometimes I *would* go on there and my partner was pretty much done, there wasn't much for me to do. But I liked doing it.

It is a new concept. Three students mentioned that they did not like using online tools; since they did not use them in previous classes, so they were not used to using them. StudentTA13 reported this reason for his negative attitude towards VoiceThread saying that:

> I did not like it (VoiceThread) a lot, just because it seems there are a lot of issues and a lot of confusion about it. It is not something we used to do, so it was kind of

> confusing…at the beginning, since it was a new concept; and I did not use in another class, it was kind of surprising.

Student TA3 mentioned the same reason for his negative attitude towards Google Documents: "I did not like the Google Documents as much, because I was not used to cooperating everything.

Audio annoying / repetitive. There was an audio recording that was reading the problems during the VoiceThread presentations. Even if, some students liked that recording and found it helpful while practicing problems, some students said that it was annoying and they could not concentrate because of that, like Student TB5 said: "It was annoying that they had a comment on the side reading it to you, when I was just trying to look up something. If you do not press pause, it keeps going."

Student TB7 explained it like this:

> *Student TB7:* VoiceThread, what I did not really like about it: I could have read the whole thing by myself, but there was a voice going.
>
> *Researcher:* So you found it annoying?
>
> *Student TB7:* A little bit… Voice was OK; it was just kind of repetitive.

Slowing down some tasks. Some features of the Google Documents did not work properly or worked really slowly in some computers. Student TB20 mentioned this slowness as a reason for her negative attitude like this: "Google Docs was kind of hard for me too, it was like I was having trouble making the diagraph, and it was just slow. It just took some time, I didn't like that."

According to Student TB21 typing was also taking a long time and slowing down her solution process: “I would like to know more about Google Docs, but to answer a question you need to scratch, you need to write down, and to do that on Google Docs you have to type and it will take more time.”

Requiring the internet access. Student TB21 mentioned a disadvantage of online tools as requiring internet access. She said: “Google Docs was nice because it automatically saves everything. It would show when the last time you edited your work. The thing is, sometimes you don’t have a Wi-Fi everywhere, and without internet you can’t do your homework.”

Mathematics and technology confidence.

When students in Online-Tools classes talked about their confidence, sometimes they could not distinguish the effect of the curriculum and the effect of online tools. Since the focus of this research question is effect of online-tools, specifically the quotes from students that especially address the online tools and its effects on their confidence are presented. The quotes that were specifically about the curriculum are presented under the fourth research question. Figure 4.16 below demonstrates the changes on students’ confidence level after using online tools with their percentages.

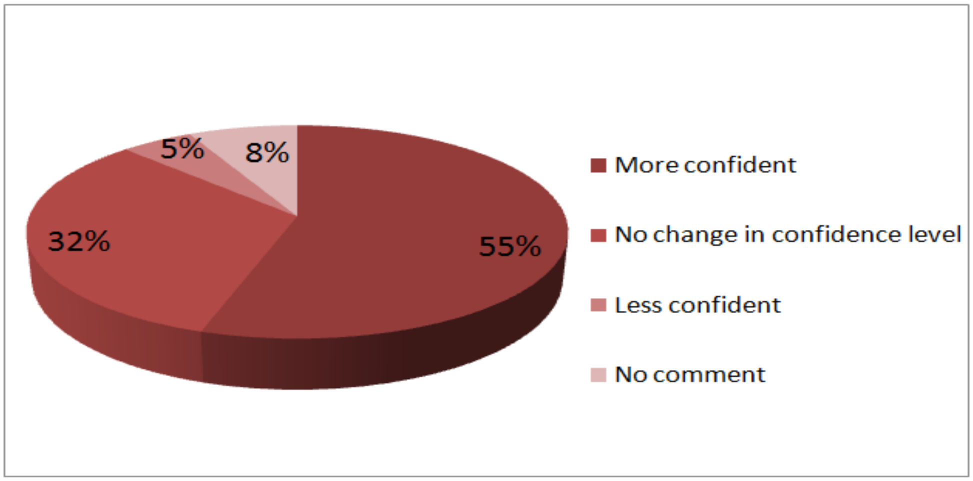


Figure 4.16. Change on students' confidence level with percentages after using online tools.

More confident. As presented previously, most of the students liked using more technology in their mathematics class. Some students reported that using more technology as a reason for the raise in their confidence. For example, when Student TA14 was asked if the online tools made any change on her mathematics and technology confidence; she said: "I think so (using VoiceThread and Google Documents made me more confident). It is helping me understand the math using a different way instead of just paper and pencil... It is a little bit more enjoyable." Student TA10 also reported that she liked using technology and she felt a little more confident when she used technology even if she does not feel confident in mathematics classes in general:

> *Student TA10:* I am overall bad at math, so cannot really improve huge great deal, but I liked the hands-on, and the fact that it is more up to date and more of technology, because the generation is whole like more technology.

Researcher: So you liked using these technologies to learn math, you feel more confident about math and technology?

Student TA10: Right.

Some students specifically emphasized VoiceThread or Google Documents helping them to feel more confident. For example, when Student TA21 was asked if the online tools made any change on her mathematics and technology confidence; she said: "Yes (using VoiceThread and Google Documents made me more confident). When I first heard about AFM I thought it was harder than that. It is actually a lot easier to get at home and work on stuff through VoiceThread than book problems." When Student TB6 was asked the same question he had a similar comment for Google Document, he answered the question saying: "I little (using VoiceThread and Google Documents made me a little bit more confident). I've never used Google docs and I thought I was going to have a nightmare with it but it was easy to use and it helped with math because I would always go on the computer so I would just bring that up and I could just do it."

Interestingly TB12 mentioned that she felt more confident about using technology after using online tools; since it was a required assignment for the class and she had to do it. She said: "Yes (using online tools affected my confidence), because this was something we had to do, it was a homework assignment. I have to work confidently on the computer."

No Change in confidence. Students who reported no change on their mathematics and/or technology confidence; usually mentioned two reasons: (a) the content of the class and the technology skills that they needed to use online tools were basic and easy, (b) they were already completely confident about mathematics and /or technology. For example StudentTA8 answered the question if the online tools made any change on her mathematics and technology confidence saying:"Not really (using VoiceThread and Google Documents did not make me more confident). I am pretty confident with technology. It was kind of a basic." And StudentTB6 said: "Not really (using VoiceThread and Google Documents did not make me more confident), just made it more exciting." So even if they said they do not feel any more confident or less, most of them mentioned using online tools made the class somehow different than other math classes. Some of them said the class was more enjoyable or exciting, like Student TB6 above; and some of them said it offered an alternative way to learn mathematics, like StudentTA9 as she said:

> I have always been really good at technology. It was not a lot of deep math. It did not hurt my math skills; it did not do much to help either. It was kind of a little bite of reinforcement. Using the tools did not increase my math skills, but it has just increased the way I do things.

Less Confident. Two students reported that after using online tools they felt less confident. Both of them mentioned this was a different way to do mathematics that they were not used to and they do not feel comfortable while working with technology in general. Below are StudentTA7's comments about why they felt less confident after using online tools:

> *Student TA7:* It (using online tools) made me less confident.
>
> *Researcher:* In terms of math or technology?

Student TA7: It was technology definitely. I do not like using technology in general, especially… I do not know, we did not grow up with it. I guess, I could say.

Researcher: What about your math confidence?

Student TA7: As far as what we are learning, as far as the chapters, I did have a lot of confidence about what I was doing, because it was a different way of learning. It is more work.

Teacher perceptions.

Even if there is not a consensus between the researchers about the key concepts that should be considered for the attitude measurement; confidence and engagement are given among the most important measures of attitude (Galbraith and Haines, 1998; Vale and Leder, 2004; Pierce et al., 2007). In this regard to investigate teachers' perceptions about the students' attitude, the interview question below was asked to teachers. Teachers wrote weekly reflections about student attitude (see Appendix G for the all the reflection probes) as well. The related reflection probe (reflection probe 5) is also given below. Since the researcher thought it would be hard for teachers to observe students' confidence, the confidence component was not included in the interview questions and the reflection probes; but even if it was not asked, Teacher B also talked about her students' confidence as seen below:

Q3: Did you observe any difference in their engagement when your students used online tools?

Reflection Probe 5: Can you describe student attitudes when they used online tools?

Teachers had different ideas about their students' engagement when they used online tools. Mostly Teacher A reported that she observed a higher engagement when students were using VoiceThread and Google Documents; while Teacher B mentioned that she did not observe any effect of online tools on student engagement. When asked the interview question above, Teacher A said:

> I will say that I do think, because their (Online-Tools class) level of engagement was greater using the Google Documents. Because they had constant reminders, not constant reminders, but "remember, you need to submit this through the Google Documents, etc." They did…it seem to me that more students were engaged to actually working in the Google Documents than if they suppose to turn in a separate piece of paper.

In her reflection for Chapter1, Teacher A said: "Students were actively engaged in this chapter. I like the VoiceThread and many students said that they liked this tool". In this regard, according to Teacher A, both VoiceThread and Google Documents had a positive impact on student engagement.

Teacher B reported that she could not observe any impact of online tools on student attitude, and she usually mentioned that it might be because of the time period of the study. Case 2 part of this study took place at the end of semester, and according to Teacher B most of the students would not be engaged anyway; since most of their grades were already given. When I asked her the interview question above, she said: "Not right now, no, and I think it would be interesting and worthwhile to start at the beginning of the semester and carry it throughout and see if that impacted it.” For the question whether there is a difference on her students’ attitudes, when they used online tools, she said: “No, just the same thing, they would rather do homework on paper and it’s probably just because that is what they’re comfortable and used to.” When the low participation for VoiceThread and Google Document assignments for her Online-Tools class were discussed with her, she said: “I think it’s possible that there are some kids that no matter what you do they’re not going to do anything.” She explained the differences in student engagement between her two classes; 1st period: Online-Tools class, 2nd period: No-Tool class; throughout the semester like this:

> I would say that’s a big difference between the two classes and why I would say that 2nd is stronger as opposed to 1st because they maybe have more motivation to let me see what I get first to make sure I did it right and then check with somebody as opposed to 1st period “well what did you get, how do you this, well I did this”. That doesn’t bother me but I think it’s a difference of motivation where as 2nd period is I’m going to do this for myself and see if its right where 1st period is maybe more tentative and maybe not as confident and so they want somebody to help them throughout the whole thing.

Research Question 4

Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

Student outcomes.

Seventy five students completed attitude survey, MTAS, at the beginning and at the end of the implementation. Thirty four students were in the Online-Tools classes and forty one students were in the No-Tool classes. The survey responses were analyzed with block design t-tests to examine whether “Post-Pre” survey was significantly different from zero for Online-Tools and No-Tool classes (see Chapter 3 for the information about the validity and the reliability of MTAS). The same analyses were done for whole scale first, and then for each subscale. Table 4.12 provides the information about the test results for the Pre-survey (completed at the beginning of implementation) and Post-survey (completed at the end of implementation, see Chapter 3 for full study timeline). Since the p-values > 0.05, the conclusion can be made that there was not a significant difference between Online-Tools and No-Tool classes over the whole scale; and for Mathematics confidence [MC], confidence with technology [TC], and behavioral engagement [BE] subscales. There was a significant difference between Online-Tools and No-Tool classes for the affective engagement [AE] subscale with 95% confidence level (p-value = 0.0178 < 0.05); and for attitude to learning mathematics with technology [MT] subscale for 90% confidence level. For the AE subscale the Online-Tools classes had a higher mean than the No-Tool classes for the post-survey; while for the MT subscale the No-Tool classes had a higher mean than the Online-Tools classes for the post-survey. These results imply that the impact of online tools may differ in terms of the emotional, behavioral, and cognitive aspects of student attitude.

Table 4. 12

The means, standard deviations, p-values and sample size of the t-tests for the pre- and post surveys

N = 75		*M (SD)* pre-survey	*M (SD)* post-survey	Pr > |t|
Whole Scale	Online-Tool	68.59 (10.75)	69.29 (15.42)	0.3533
	No-Tool	66.59 (11.03)	66.59 (10.60)	
BE subscale	Online-Tool	13.76 (3.38)	13.65 (3.26)	0.3375
	No-Tool	13.98 (3.23)	14.12 (2.77)	
TC subscale	Online-Tool	15.32 (2.88)	15.35 (3.73)	0.5401
	No-Tool	14.98 (2.44)	15.22 (2.66)	
MC subscale	Online-Tool	13.03 (3.34)	13.09 (4.61)	0.8274
	No-Tool	12.27 (3.30)	12.20 (3.35)	
AE subscale	Online-Tool	12.00 (3.36)	12.88 (4.00)	**0.0178***
	No-Tool	12.29 (3.35)	11.51 (3.59)	
MT scale	Online-Tool	14.47 (2.94)	14.21 (4.08)	**0.0714**
	No-Tool	13.07 (3.91)	13.54 (3.16)	

* This is p-value with a Kenward Rogers Approximation for the degrees of freedom.

Subscales**:** Mathematics confidence [MC], confidence with technology [TC], attitude to learning mathematics with technology [MT], affective engagement [AE], and behavioral engagement [BE].

The results of this study show a statistically significant difference for the affective engagement between the Online-Tools and the No-Tool classes for $\alpha = 0.05$.

For more detailed analysis of the different aspects of student attitude, the qualitative findings are presented later in this study. Even if there was not a statistically significant difference between pre- and post-survey of the Online-Tools and the No-Tool classes based on t-test results; the Table 4.13 and Table 4.14 below present that there are differences in the distribution of MTAS subscale scores. The numbers in the tables are pictured in the box plots in Figures 4.17 and 4.18

Table 4. 13

The distribution of MTAS subscale scores for Online- Tools classes for the pre- and post-surveys

Online-Tools Classes	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre		BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	5	9	7	4	5		8	7	4	5	4
Q1	11.25	14	11	10	13.25		11	13	9.25	11	11.25
Median	14.5	15	12.5	12	14.5		14	15.5	14.5	12.5	16
Q3	16	17	15.75	14	16		16	18.75	16	15.75	16
Max	20	20	20	20	20		20	20	20	20	20

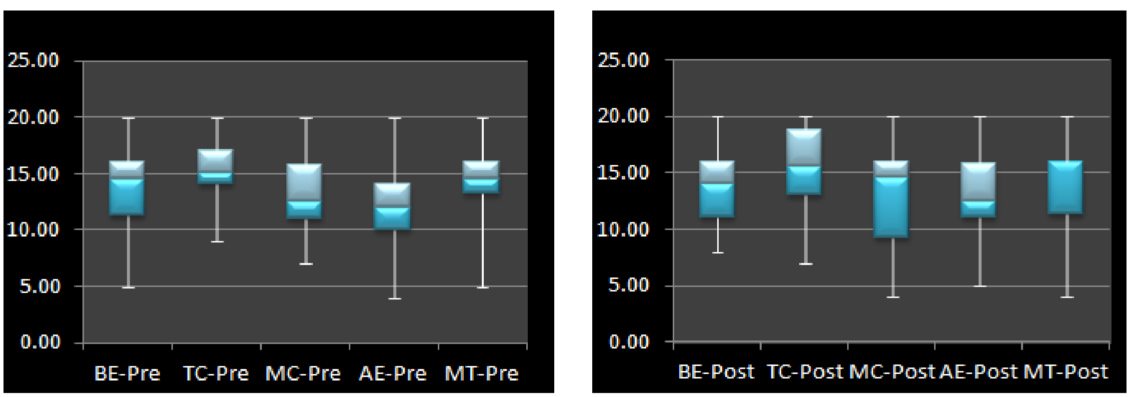


Figure 4. 17. Box plots presenting the distribution of MTAS subscale scores for Online Tools classes for pre- and post-surveys.

Table 4. 14

The distribution of MTAS subscale scores for No- Tool classes for the pre- and post-surveys

No-Tool Classes	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre		BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	7	9	4	4	4		9	9	4	4	4
Q1	12	14	10	10	11		13	14	10	10	12
Median	14	15	12	13	13		14	15	12	12	13
Q3	16	17	14	15	16		16	17	15	14	15
Max	20	20	20	19	20		20	20	20	18	20

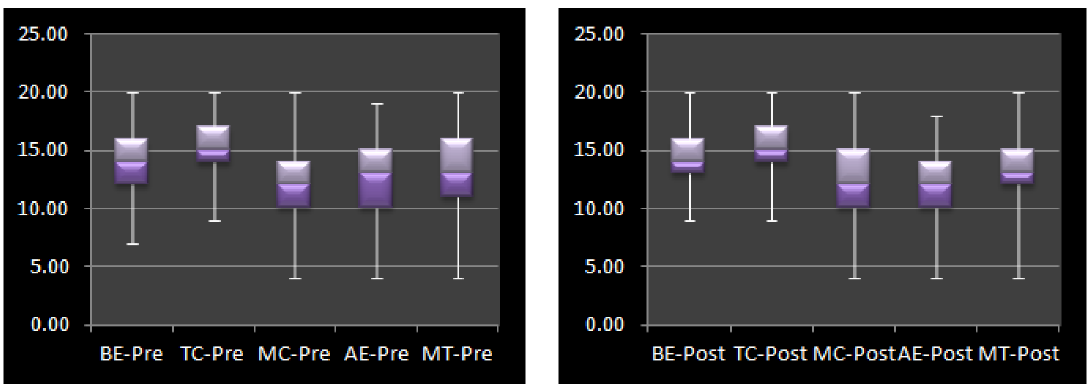


Figure 4.18. Box plots presenting the distribution of MTAS subscale scores for No-Tool classes for pre- and post-surveys

Even if the differences between pre- and post-survey of Online-Tools and No-Tool classes were not significant for all the subscales based on the t-tests (see Table 4.12), a lot of differences are seen between pre- and post-survey results on minimum, maximum, median, upper and lower quartiles for some of the subscales. For example, for the MC (mathematics confidence) subscale for Online-Tools classes (see Table 4.13): The median is 2 point greater for the post-survey which means: 50% of the students score greater than or equal to 12.5 in the pre-survey; while 50% of the students score greater than or equal to 14.5 in the post-survey. At the same time the upper quartile is 0.25 point higher for the post-survey, which means: 25% of the students score greater than or equal to 15.75 in the pre-survey, while 25% of the students score equal to 16 in the post-survey. On the other hand, the lower quartile is 1.75 point lower for the post-survey; which means 75% of the students score greater than or equal to 11 in the pre-survey, while 75% of the students score equal to 9.25 in the post-survey. The minimum score is 3 point lower for the post-survey than the pre-survey. Those changes are not seen for the No-Tool classes for the MC subscale. Only the upper quartile is 1 point greater for the post-survey, and all the other variables stayed the same from pre-survey to post-survey. We see similar differences for other subscales between Online-Tools and No-Tool classes as well. These differences and the t-test results given in Table 4.12 are discussed in Chapter 5. To triangulate with the quantitative results that were presented above, the qualitative results for the fourth research question research are presented below.

Student perceptions.

To investigate attitude differences and similarities between Online- Tools and No-Tool classes, all students were asked the interview questions below both in the Online-Tools and No-Tool classes:

> Q12: How confident are you about your learning of the content of this class and how confident were you in your previous mathematics classes?

Q13: Do you think this class has changed your mathematics and technology confidence, and your beliefs and feelings about mathematics?

Student answers to Q12 coded in five categories: completely confident, quite confident, fairly confident, not confident, and no comment for their confidence in current mathematics class and their mathematics confidence in general. Figure 4.19 provides the information about the number of students in each category for each class.

Confidence Level in current class	**% of Students (Online-Tools classes)**		**% of Students (No-Tool classes)**	
	Teacher A	***Teacher B***	***Teacher A***	***Teacher B***
Completely confident	16	33	10	31
Quite confident	56	67	60	63
Fairly confident	16	0	20	6
Not confident	4	0	10	0
No Comment	2 students	0	0	0
Confidence Level for mathematics in general	**% of Students (Online-Tools classes)**		**% of Students (No-Tool classes)**	
	Teacher A	***Teacher B***	***Teacher A***	***Teacher B***
Completely confident	16	20	0	6
Quite confident	52	60	60	31
Fairly confident	16	7	40	50
Not confident	8	7	0	13
No Comment	2 students	0	0	0
Other	0	1 students (depends on the content)	0	0

Figure 4.19. Confidence levels for current and previous mathematics classes.

The percentages in Figure 4.19 represents that the percentage of students in the Case 1 Online-Tools class who feel at least fairly confident in the current class is a little bit higher than the percentage of the students who feel at least fairly confident in other mathematics classes. For the Case 1 No-Tool class, the percentage of students who feel at least fairly confident in the current class is lower than the other classes. For the Case 2 Online-Tools class, all of the students feel at least quite confident in the current class; while some of them were fairly confident or not confident at all in other mathematics classes. For the Case 2 No-Tool class, all of the students feel at least fairly confident in the current class; while more than 10% of them were feeling not confident in other mathematics classes. These numbers imply that the current class strengthened the confidence of all the students in all four classes; while the level of this strengthening is a little higher for the Online-Tools classes.

Below some exemplar student comments are presented demonstrating different confidence levels for previous mathematics classes and current class based on their responses to Q12 above. Then student answers to the Q13 are presented under three categories: more confident, no change, less confident; which refers to the change in student confidence level for mathematics and technology comparing to previous mathematics classes and previous experience with technology.

Confidence in current class and about mathematics in general.

Completely confident. Student confidence level about mathematics in general and in the current class were coded as *completely confident*; if (a) the students told that they were "very confident"; or (b) they gave "9 or 10" when asked them to rank their confidence level on a scale of 1-10; where the 10 is the best. For example, when Student TA6 was asked about her confidence in previous mathematics classes, she said: "The only math class in high school that was difficult for me was probably geometry with all the different shapes. But everything else, I am pretty good with numbers doing stuff like that. I am very confident about solving math problems." When I asked Student CB29 to rank her confidence in previous mathematics classes on a scale of 1-10; she gave a "9" for her confidence.

For the current class, students who reported themselves as *very confident* from both Online-Tools and No-Tool classes and from both cases mentioned that the content of the class was easy for them to understand. They usually compared the current class with the algebra classes they took. For example, when Student CB24 was asked to rank her confidence in current class on a scale of 1-10, she said that: "I would say 9 or 10… It (current class) is easier, like compared to algebra." Similarly Student TA18 said that: "It (current class) was really easy to grasp. It was not like super hard or anything, you just need to pay attention." According to Student TA22 current class was really different than other mathematics classes: "This (current class) is not actually a math class. This is not a serious math; we are just doing problem solving."

For some students, the content was really related to their future career which made them confident in class. Student CA5: "I am very confident, because this is what I want to do, like I want to do business so it helped me with like making decisions, so it was good." For some students it was important to make connections with real life situations, while solving problems in class. StudentTB1: "In this class I am actually understand it, I'm getting all of the material, I understand what I am doing, and I understand how I can take this put this into real life when I get older, how I can use this in my career or whatever."

Quite confident. Student confidence level about mathematics in general and in current class coded as *quite confident*; if (a) the students told that they were “pretty confident”; or (b) they gave “7 or 8” when asked to rank their confidence level on a scale of 1-10. For example when Student TA8 was asked to rank his confidence in mathematics classes, he gave an 8 on a scale of 1-10 and he said: “I am not seriously strong at math, but I am good at math.” Student TA15 said that “I am pretty good at math; and I pretty much like that.” for his confidence in mathematics classes.

Interestingly some students in Online-Tools classes emphasized that for them the technology was not the effective factor for their confidence in class, like Student TB17 reported himself as pretty confident in class. When asked if he can differentiate the effect of the content of the class from the effect of the technology on his confidence, he said: “It (his confidence) would be the same without the technology, especially for this class. For a more challenging class, it would have been different.” StudentTB5 had a similar comment: “I am pretty confident…In general I am better in this class, but as far as the Google Docs and VoiceThread… it is helping you to learn a little bite, but not much. I learned most of it from my teacher.”

Fairly confident. Student confidence level about mathematics in general and in current class coded as *fairly confident*; if (a) the students told that they were “fairly confident”; (b) they gave “5 or 6” when asked to rank their confidence level on a scale of 1-10, or (c) they could not decide if they were confident or not. For instance when

StudentTA20 was asked if she feels confident in mathematics classes, she said: "Sometimes yes."

For the current class Student TA14 said: "I am in between confident and not-confident." and Student TA3 said "I am fairly confident… I think it has been easier in this class than some of my previous ones. This curriculum is just slightly easier. I do not know why, but I can understand it quickly. I guess, it is not fast pace."

Not confident. Student confidence level about mathematics in general and in current class coded as *not confident*; if (a) the students told that they were "not confident"; or (b) they gave less than 5 when asked to rank their confidence level on a scale of 1-10. For instance when StudentTB5 was asked her confidence in math classes, she said that she did not feel very confident and she ranked her confidence as 4 on a scale of 1-10. Similarly StudentTA10 said: "I have never been confident in math. I had to have math tutors, I am not very confident in math. It has always been hard for me." And, StudentTA13 said: "No, not really", when I asked him if he feels confident in current class.

No Comment. Student confidence level about mathematics in general and in current class coded as *no comment*; if (a) the students told nothing; or (b) if it was not clear if she/he was confident or not from her/his response to the question. One example is when StudentTB21 was asked about her confidence in her current class, she said: "I enjoy learning things. My parents encourage me to learn new things… would make it enjoyable for me, because I always like to know more."

Change in confidence level. The interview question below was asked students to investigate the change in their attitude towards mathematics and technology:

Q13: Do you think this class has changed your mathematics and technology confidence, and your beliefs and feelings about mathematics?

Some exemplar student answers are presented below in three categories: more confident, no change, less confident, which refers to the change in students' confidence level after taking current class. Then some exemplar student comments about their beliefs and feelings about mathematic before and/or after class are presented.

More confident. When students were asked about the change in their math and technology confidence after taking the current class, those who said they feel more confident mostly reported that they feel more confident about both mathematics and technology and mentioned different reasons for that. For example according to Student TA27, she felt more confident about technology; since he used Google Documents that he had never used before, and gained some new skills. When Student TA20 asked if she feels any change in her mathematics confidence, she said: "I do not know it helped a lot…It is a different type of math that I am used to. So I found it easier. It is a lot less stressful now." Student TA23 answered the same question saying: "Uh, yeah I used to be scared of math and I feel like this class is a breeze." And, for the question if he feels any difference in his technology confidence, he said: "Yeah, I'm not very good at computers, and I learned how to use a spreadsheet for the first time in this class; so definitely." Student CA5 answered the same questions saying: "Yes (there is a change in her confidence level), positively because like since we got to use computers, like I can use Excel now, like I know how, and math, like because I actually get it I am confident now."

Some students felt different for their confidence about math and about technology:

Student TA24: In confidence, yeah and what we did yeah; because now I kind of I know how math is really used in real life.

Researcher: So you feel more confident in math?

Student TA24: Yeah.

Researcher: And what about your technology confidence, is there any change in that?

Student TA24: Not really I mean it's the same technology used in everything just used differently so my opinion towards technology didn't change.

No change. Some students reported that they felt no difference in their confidence level in terms of mathematics or technology. For instance when Student CA4 was asked if the current class made any change on her confidence, she said: "Not really, I mean I know I can do math, but I never really had a confidence in it", which implies she has a really strong negative feeling about her confidence in mathematics. Student CA22 talked about her confidence and thoughts about the class more in detail:

> Um I don't think it has altered it (my confidence) too much, it is pretty much the same, and it is like a different kind of math than before… I like this (current class) more than other classes, because it is not like new math it has ways of applying math you already know.

Less confident. Even if most of the students reported that they felt confident in current class, Student CA11 reported that she felt less confident in current class than other mathematics classes. He mentioned that the current class had a negative effect on his mathematic confidence and technology confidence. When asked the reason he said: “Negative because I used to pass all my tests and quizzes in other math classes and in this class I feel stupid like I don’t know anything.”

Beliefs and Feelings about math. In terms of the impacts of the current class on students’ beliefs and feelings about mathematics, students mostly had really positive comments about the different aspects of the class. They usually emphasized how it helped them to realize and learn about the applications of their mathematics knowledge that they got from other mathematics classes. This realization increased their appreciation to mathematics as a field. For example, Student CA5 said: **“**I actually like math now, because it …like applied to real life, so I’m like maybe it is useful.”

According to Student CA7 the current class did not increase her attitude towards math, but it was easier to grasp: “Um it is still not my favorite subject but I do understand it more than I have any other time, like when we go over stuff, I learn it easier than I have in any other class.” Similarly Student CB12 said: “It just, it made me realize that some math doesn’t have to be so complex and there can be simple ways to do certain things.”

At the same time most students mentioned that the current class had a really different structure than other mathematics classes. Student CA1: “This one (current class) doesn’t really feel like a math curriculum really, it’s much more to do with decisions and also to use a lot more of Excel. So it doesn't feel exactly like a math class." Most of the students mentioned that they like the class structure and how it relates their mathematics knowledge with real life in a logical sense. StudentCA4 said: "I kind of like this class in some aspects just because I like it when you do a lot of logical steps." Student CB15 explained why she felt more confident in current class and how her beliefs changed about mathematics like this:

> I think that it (current class) has changed it (my confidence), a little bit higher for sure. Because algebra and geometry like put me down on myself about math and I thought "oh my Gosh, I'm never going to learn anything" and I didn't know that discreet was going to be, that I would actually be good at discreet. Before I just thought that I was horrible at math and that I will just never get math. But I get this math, so maybe it's just, like it's made me think maybe some math I'm just not good at and I'm good at other ones, instead of just math in general.

StudentTA8 mentioned his interest in computer programming and likened the current class with programming:

> It (current class) kind of reminds me computer programming. It is more like "if this, then" kind of equations. Not necessarily number based, but variable based. Change overtime, those kinds of things, taking the account different scenarios; like what we are doing in decision trees like random events and those kinds of things. I want to say it is very math-based in the sense of numbers, but logically it is different than the other classes I have taken.

Student CA18 told that he does not see any change on his beliefs about math after taking the current class, but he related it to his future career and named the current class as an adjustment for college:

Researcher: So is there any change after this class about your beliefs and feelings towards mathematics?

Student CA18: Um, it hasn't really changed it much, because you know to me it is essentially another class, another math class just with different criteria. It hasn't really changed my views; I've had the same views about math for a while.

Researcher: So what do you plan to study in college, engineering?

Student CA18: That's actually what I want to study.

Researcher: Oh, ok. Because you know this curriculum is more related to engineering.

Student CA18: Yeah.

Researcher: Maybe it may help you in this way.

Student CA18: Yeah I mean if you look at it that way, it's I guess its eye opening and it is something to expect or look forward to. And I mean I think it is just more along the lines of getting used to it. Cause I mean it's different from all my other math classes, so I think it's just a bit of an adjustment.

Summary

The major findings and the detailed analysis of the findings have been presented in this chapter. For the first research question: student interaction, communication and collaboration were analyzed. A framework that was developed by Stahl (2006) was used to examine the student collaboration on personal understanding and social knowledge building level. For the analysis of student-content and student-teacher interactions a second framework that was developed by Anderson (2008) was used. Additional findings were presented as well to investigate the reasons for students' chat use and for students not participating in the Google Document assignments. The second question was about the impacts of using online tools on student learning. The analysis revealed that for the Case 1, Advanced Functions and Modeling classes, the quantitative results presented more improvement for Online –Tools class than the No-Tool class; while for the Case 2, Discrete Mathematics classes, No-Tool class had higher improvement in average grades than the Online-Tools class. These results imply that for easier concepts online tool use could be less effective. On the other hand, qualitative findings demonstrate that the majority of the students had positive perceptions about the impacts of the online tool use on their learning in both cases. The third and fourth research questions were about the student attitudes towards mathematics and technology. Statistical analysis of the attitude survey revealed significant differences between Online-Tools and No-Tool classes for only affective engagement subscale on 95% confidence level. For the other subscales there were some variations on the minimum, maximum, mean values, and the standard deviations as well from pre- and post-survey; even if the difference between Online-Tools and No-Tool classes was not significant. Based on the student interviews, majority of the students had positive attitudes towards using the online tools, Voice Thread and the Google Documents, in their mathematics class. Some students reported improvement on their mathematics and technology confidence after using online tools. The reasons for positive and negative student attitudes have been presented above in detail. Students also mentioned an improvement on their feelings and beliefs about mathematics after using online communication and collaboration tools in their mathematics class. The detailed discussion of the major findings is presented in the next chapter (Chapter 5).

CHAPTER 5: DISCUSSION

The purpose of this revelatory case study was to investigate the integration process of the online communication and collaboration tools, namely VoiceThread and Google Docs, into high school students' mathematics education and their impact on student attitudes and learning within an authentic curriculum. The study was guided by the following research questions:

> (RQ1) How do student-student interactions, communication, and collaboration develop with the support of online technologies in an authentic mathematics curriculum?
>
> (RQ2) How does interaction, communication, and collaboration via online tools impact on student learning of an authentic mathematics curriculum?
>
> (RQ3) In what ways are students' emotional, behavioral, and cognitive attitudes affected by uses of online tools in a blended, authentic mathematics curriculum at the high school level?
>
> (RQ4) Do emotional, behavioral, and cognitive attitudes differ between students using online tools and students using no tools?

In this chapter the noticeable findings for each research question are discussed and expanded. The discussion is presented in two parts: research question 1 and research questions 2-4. This structure was followed, since the first research question was about the integration process of the online tools and other questions were about the student outcomes.

Since a theoretical framework was used to answer the first research question, the findings based on the framework and possible modifications are presented for the discussion of the first research question. Then, teachers' perceptions about the student participation for the assignments using the online tools are presented along with the teachers' suggestions as to how to get more participation from the students. For research questions 2-4, presented first are the differences between Case 1 and Case 2 and the possible reasons for those differences, which may have implications for all three questions. Then separate discussion points are presented for each question (2, 3, 4). After the discussion about the research questions implications for practice, affordances of the Voice Thread and the Google Documents, and suggestions for future research presented and discussed. Finally conclusions are presented at the end.

Research Question 1: Reflections on the theoretical framework.

The findings for the first research question were presented based on the frameworks suggested by Stahl (2006) and Anderson (2008) in chapter 4. In this section, the discussion of the findings and possible combinations and modifications of the two models are presented. According to Bruns and Humphreys (2005), computer use for educational purposes should not be limited to only delivery of basic content, but instead should include more collaborative teaching and learning applications as well. As explained in detail below, in this study the use of VoiceThread and Google Documents for authentic mathematics problems was inclusive of a *variety of interactions* that occurred along a continuum that includes student-student, student-teacher, and student-content interactions.

Based on the findings of this study, the researcher suggests that Stahl's framework provides a strong starting point for the discussion of social knowledge building in CSCL environments, and makes crucial connections between students' personal understanding and social knowledge building. However while Stahl presents a detailed representation of social knowledge building in his model, the model does not include some really influential factors such as student-content and student-teacher interactions when they use online technologies for communication and collaboration purposes. On the other hand, even if Anderson includes in his model several components that occur in a computer mediated environment, he did not give a detailed representation as Stahl has done for the social knowledge building process. So by combining these two models, the researcher suggests a framework for understanding mathematics learning in blended form for the analysis of social knowledge building when students use online tools for communication and collaboration purposes. Anderson's model helped the researcher to recognize that during the social knowledge building process other interactions occurred, such as student-teacher interaction, and Stahl's model helped the researcher to present details about student-student interaction process.

Stahl's model is used as the basis for student-student interactions. When students use communication and collaboration tools to solve mathematics problems, the solution process can be either collaborative or cooperative based on the findings of this study. So, the researcher added a cooperative knowledge box to Stahl's model (see Figure 5.1). In addition, the findings of this study revealed direct relationships among student-student, student-content, and student-teacher interactions. Thus, the researcher suggests that all three types of interactions constitute the social knowledge building cycle (Figure 5.1). There is a two way transaction between personal understanding and social knowledge building through public statements. As argued by Stahl, individuals enter into the social process through public statements by explicating their understanding. It was observed in this study that sometimes others' public statements have a direct impact on an individual's personal understanding. So, the relationship between personal understanding and social knowledge building is a two way relationship. Figure 5.1 below presents all those relationships with additional components in a Modified framework combining Stahl's and Anderson's models. Detailed explanations of each component are presented below.

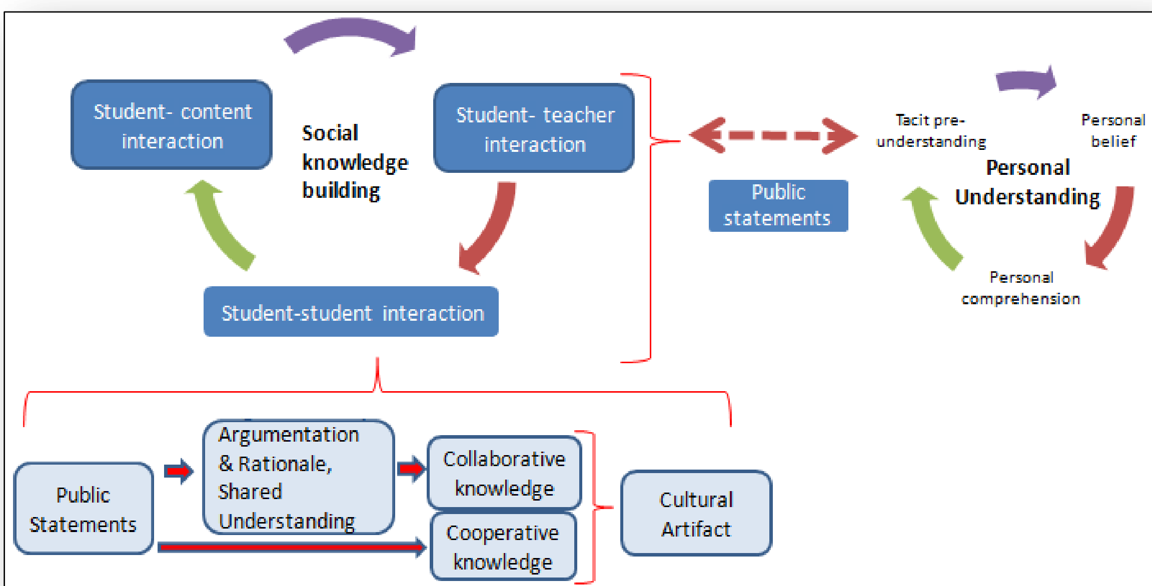


Figure 5. 1. Modified framework combining Stahl's and Anderson's models.

The *cooperative knowledge* component appearing in the Modified framework (Figure 5.1) that was added to Stahl's original framework is based on the results of this study. As explained in detail in Chapter 4, for some problems students divided the solution of the problem into small parts and shared those parts with each other. Then each person shared the solution to her/his part in the Google Document with others, which is referred to as their public statements. So, for those problems students skipped the discussion, negotiation, and clarification steps and demonstrated a *cooperative solution* to the problem instead of a *collaborative solution* as presented in Figure 5.1. Roschelle and Teasley (1995) assert that: "Cooperation is accomplished by the division of labor among participants, as an activity where each person is responsible for a portion of the problem solving..." and they defined collaboration as "...the mutual engagement of participants in a coordinated effort to solve the problem together" (p. 70). In this study, for some of the problems students not only skipped the discussion and negotiation steps, but they also divided the labor between each other and did not demonstrate a mutual cognition. On the other hand, for some problems they communicated with each other, and had arguments and negotiations before going through a shared understanding; which is the process of developing a collaborative knowledge. Thus the collaborative knowledge and cooperative knowledge boxes refer to the results of different processes, so both are needed in the Modified framework in Figure 5.1. The arrow going from others' public statements to cooperative knowledge in the figure explains that different students' public statements in a group generate the group's cooperative knowledge. This cooperative knowledge directly forms the cultural artifact. The arrow from *others' public* *statements* to *personal comprehension* represents that for some students their peers' statements in the Google Document helped them to achieve comprehension of the content.

The projects or homework problems for which students reported that they have worked cooperatively instead of collaboratively mostly had multiple parts that could be easily divided among the students. For example, for the Chapter 2&3 project (maximum and minimum problems); student were asked to write their own maximum and minimum problem and solve them. For that project, the teacher first asked students to write the problems, and then solve one another's problem. However, students preferred to solve the problem that they wrote instead of solving their partner's problem. Some other projects and homework problems for which students worked more collaboratively had a more integrated structure with multiple steps that were interdependent. In this case, the researcher argues that observing cooperation or collaboration among students is directly related to the structure of the problems. So, educators (teachers, designers, etc.) should consider that: if the structure of a mathematical problem does not necessitate collaboration; it is highly possible that you will observe more cooperative work by students instead of collaborative work. Thus, appropriate problems should be chosen depending upon the educational goals. For example, if the purpose of using tools is to build more discussions, negotiations, and argumentation among students; then the problem structure should require those steps to reach the solution. If it does not, students will not necessarily collaborate to solve the problem, even if it is recommended by their teacher. Another way to require collaboration among the students is to make collaboration a part of the assessment; so they can get credit if they complete the problem collaboratively.

Bernard et al. (2009) argue that through different types of interactions, students' comprehension of the content can be increased. Student-student, student-content and student-teacher interactions are among the most common interaction types in online interactions (Moore, 1989 as cited in Ertmer, Sadaf, and Ertmer, 2011). Student-student interaction has already been analyzed and discussed in the document with the help of Stahl's model above. Student-content and student-teacher interactions are not a part of Stahl's model; but they are a part of Anderson's (2008) framework and they were observed in this study. The details about those interactions are presented below.

Ertmer, Sadaf, and Ertmer (2011) suggest some typical ways of student-content interaction such as through course readings, engagement with multimedia materials, or course assignments. On the other hand, the authors argue that "participation in course-related online discussions can also facilitate student-content interactions" (Ertmer, Sadaf, & Ertmer, 2011, p. 158). In all forms the ultimate goal is to promote student learning of the material. In this study, two types of interactions developed between the students and the content via their participation in assignments with the online tools. For the Voice Thread assignments, students directly interacted with the content by practicing problems with the Voice Thread presentations. They were also required to answer some questions during their practice. For the Google Document assignments, students were required to put their mathematical thinking in words through the Google Documents and solve mathematical problems by collaborating with their partners. As presented in Chapter 4 (Findings), a lot of student reported that Voice Thread practices and answering questions during the practice helped them to understand the course material better. Some students reported also that they benefited from the Voice Thread presentations to develop their public statements in the Google Document assignments. The student-content interaction through the Google Documents was naturally a part of the social knowledge building process, since it shaped the form of student public statements in the Google Document.

Cavanaugh, Barbour and Clark (2009) reviewed 226 publications on K-12 online learning and conducted a content analysis. They found that 83% of the publications reported the teacher as being the most influential factor of success of any virtual school because of their direct contact with students. In this study, student-teacher interaction through the Voice Thread affected students' public statements in the Google Document, since it affected how students articulated their understanding. Student comments on the Voice Thread were also used in the face-to-face sessions to improve personal understanding by clarifying concepts which reflects a two-way transaction between the social knowledge building and the personal understanding that occurred through the public statements.

In conclusion, this researcher argues that interactions between students and the content; and among students and the teacher have direct impact on student-student interaction, so they should be a part of *social knowledge building* process in addition to student-student interaction. In this study; student discussions, negotiations and clarifications mostly occurred through the chat panel. There were two venues for public statements: one through the Voice Thread and one through the Google Documents; and those statements were building a bridge between the personal understanding and the social knowledge building. Figure 5.2 below presents the Modified framework that was presented in Figure 5.1 for this study with details added:

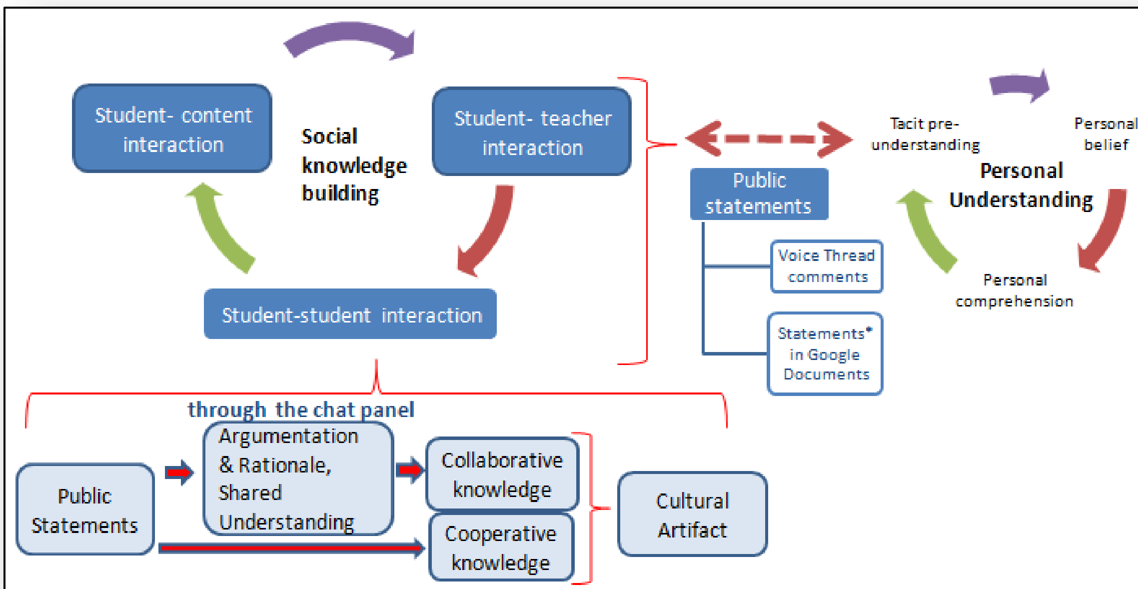


Figure 5. 2: The particular form of the general framework for the study. Discussions, negotiations and clarifications occurred through the chat panel in this study and Voice Thread comments and statements occurred in the Google Documents. These were the two types of public statements in this study.

Teacher Perceptions.

During the interviews, teachers talked about why students did not use Google Documents effectively according to their observations and they made some suggestions for higher levels of communication and collaboration through the Google Documents. For example, Teacher A said: "Since they know they will see each other on the next day in school, they prefer to communicate face-to-face. If this course was online, student might communicate through the document more." She gave the text message example. She said if we had asked students to use text messages to communicate, they might prefer to call each other. However, if we tell them no one will answer the phone when they call, they would need to use texting more. So, she emphasized the importance of *necessity*. When this researcher asked her, why she thinks it worked this way; she mentioned two of the same reasons students mentioned: (1) face-to-face/ chat is faster and (2) procrastination. She also talked about how it could be harder for students to communicate and collaborate for a math project than it is chatting about daily life:

> I do not know, I mean as much as they like to communicate with each other through technology, like texting or e-mailing, etc. I find it interesting that they do not want to collaborate as far as class work on that same level. I do not know if it is because… when you are communicating via text or e-mail you do not have to necessarily see that the other person is working on; but if you are working on a project, you actually have to see what that person is working on… for people who are more visual learners or who they think better visually; seeing it, sitting down, talking about it, and seeing what the other person is thinking or writing is more helpful for them. They are able to ask questions quickly … when you are in a Google Document, and you have to wait for someone to respond, that slows down the process. I also think that they procrastinated with it. They wait until the last minute or the day before or the day off.

> And then, they do not have the time to collaborate via the document. If you are going to communicate or collaborate using the documents; you have to give people time to respond to what you have done.

Teacher suggestions for higher student participation/ collaboration. Teacher A suggested checking student collaboration in the Google Documents in a timely manner and giving them reminders to participate; and using Google Document for multiple numbers of projects successively might encourage them to participate more. She said:

> If it were on going in an expanded amount of time where they were check point along the way, like on this particular day you and your partner collaborated on this piece...what ends up happening is that if it is one project or one assignment, they are going to wait to the last minute and I am not going to see a lot of collaboration; but if there is a longer process or a longer term project and there are check point along the way, I can better see the collaboration. It is going to; hopefully, force them to collaborate... With this, some things were presented through Google Documents, other things were not. So I do not know if they felt the urgency with the Google Documents. So I do not know how much time they invested in really learning the tool and using the tool… if had known every single assignment is going to be a Google Document, then it makes them…it gives them a sense of urgency of how to navigate the tool.

According to Teacher B, students would use online tools more effectively; if they could start using them earlier in semester. She said:

> Unfortunately for us timing at the end of the year is tough to get kids motivated to learn anything new. So if they started it from the beginning, you know if we were using Google documents and VoiceThreads throughout the entire course, I think that would be… for the first period (online-tools class) for the beginning part of the course they had paper homework, paper homework, paper homework and all of a sudden here is your homework on the computer. It's a big change, but if from the beginning, you know maybe not all their homework on the computer. We'll start off you have one assignment on the computer, here's some paper homework. Then you have two assignments on the computer and we're forced to work our way up to where all our assignments on the computer, that would help.

In her comment below Teacher B explained her ideas about why there was low participation in Google Document assignments and she suggested training students more about how to communicate and collaborate for mathematics problems, since they are not used to assignments for which they are required to use online tools for communication and collaboration purposes.

> I don't know how to get them to do that. I do feel like with honor students and AP students they do a lot more of that collaboration anyway and so maybe with higher students they would just naturally do that but with these lower level students we would have to kind of train them to talk to their partner because a lot of them take things at face value.

In conclusion, the findings of this study relating to student interaction, communication and collaboration resulted in the development of a Modified framework combining the models developed by Stahl and Anderson. The Modified model suggests that: (a) student work through the online tools might be either collaborative or cooperative depending upon the problem structure; (b) student-content and student-teacher interactions have direct affects on student-student interaction, so they should be a part of social knowledge building; and (c) there are two-way transactions between personal understanding and social knowledge building through the public statements. Teacher comments about student interactions were mostly parallel to student comments. Additionally, teachers made suggestions for increasing participation by students; for example, having check points along the way to motivate student participation during the Google Document assignments, and spending more time to train students about how to collaborate with each other using online tools for mathematical problem solving. Discussions for the other research questions are presented below in two sections: (1) Research Question 2, 3 & 4; where differences between two cases are presented and possible reasons for those differences were discussed; and (2) Separate Discussion Points for RQ2, RQ3 and RQ4; where additional discussions are presented for each question.

Research Question 2, 3 & 4

Considerable differences have been observed between Case 1 and Case 2 students in terms of their participation and outcomes during this study. Those differences between two cases and the possible reasons for those differences that could have implications for the second, third and fourth research questions are discussed in this section. Then, results and discussions unique to each of these three research question are presented briefly. The differences between Case 1 and Case 2 are presented below in terms of participation and outcomes.

Figure 5.3 presents a quick overview of the differences between two cases of this study and possible reasons for those differences. The researcher argues that all three factors on the left hand side could be affective on each outcome on the right hand side. In this regard, below instead of discussing each outcome; all three outcomes, differences between the Case 1 (Teacher A's classes) and Case 2 (Teacher B's classes), are presented, then the possible reasons that could be responsible for those outcomes are discussed.

Possible reasons for the differences between the Case 1 and Case 2

- The time period and the length of the implementation
- General differences between the classes of the Case 2
- Differences between the chapters (Case 2 students learned easier chapters than the Case 1 students)

Differences between the Case 1 (Teacher A's classes) and Case 2 (Teacher B's classes)

- Participation differences
- Overall average grade differences
- Attitude differences

Figure 5.3: The differences between two cases of this study and possible reasons for those differences.

Participation Differences

Considerable differences were observed between Case 1 and Case 2 students who worked on the Google Document assignments through the documents. Figure 5.4 below presents the percentages of groups that worked collaboratively (more than one partners worked on the assignment), only one person completed the assignment, and no one from the group worked on the assignment through the Google Documents. It is seen that for Case 1, the percentage of the groups that worked collaboratively is always more than 50%, while it was less than 50% for the Case 2.

CASE 1	% of Groups No one signed in	% of Groups Only one partner worked	% of Groups More than one partners worked	**CASE 2**	% of Groups No one signed in	% of Groups Only one partner worked	% of Groups More than one partners worked
Assignments				**Assignments**			
Chapter 1-FinalProject	0	0	100	Ch9-K.BaconGame	0	42	58
Ch.s 2&3-Mini Project	8	23	69	Ch.9-Homework9.5.3	25	42	33
Ch.11Restaurant Problem	15	23	62	Homework9.5.4	17	58	25
Chapter 11-Wayne State Products	0	31	69	Chapter 10-Homework10.5.2	8	67	25
				Chapter 10-Homework 10.5.3	17	58	25
				Chapter 10 -CPM Project	12.5	37.5	50
				Chapter19-Homework 3	18	64	18

Figure 5.4. Percentages of student participations in the Google Document assignments.

Overall average grade differences

As explained in Chapter 4 in more detail, the grades for the implementation and for the other chapters of the Online-Tools and No-Tool classes were averaged for both cases. Some differences were found to exist between the two cases (see Table 5.1)

Table 5.1

Difference in the average grades for Online-Tools and No-Tool classes throughout the semester for Case 1 and Case 2

CASE 1	**Other chapters**	**Implementation chapters**
Online-Tools Class	84.82 ± 9.58	86.01 ± 7.26
No-Tool Class	85.07 ± 10.38	85.57 ± 9.05
CASE 2	**Other chapters**	**Implementation chapters**
Online-Tools Class	85.24 ± 6.67	89.08 ± 7.16
No-Tool Class	86.24 ± 8.10	92.18 ± 5.48

Attitude Differences

Differences are seen between pre- and post-survey results on minimum, maximum, median, upper, and lower quartiles for different subscales for Case 1 and Case 2 Online-Tools classes; especially TC (technology confidence), MC (mathematics confidence), and MT (attitude to learning mathematics with technology) subscales.

Table 5. 2

Distribution of pre- and post- survey results for Case 1 and Case 2

CASE 1	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre	BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	5	11	8	6	5	8	8	4	6	4
Q1	11.00	14.00	11.00	10.00	14.00	11.00	13.50	8.00	9.00	10.50
Median	14.5	15	12.5	12	14.5	14	15.5	14.5	12.5	16
Q3	16.25	18.25	16	14	16	16	20	16.25	15.25	16
Max	19	20	19	18	20	20	20	20	20	20
CASE 2	BE-Pre	TC-Pre	MC-Pre	AE-Pre	MT-Pre	BE-Post	TC-Post	MC-Post	AE-Post	MT-Post
Min	8	9	7	4	9	8	7	4	5	8
Q1	13.5	14	10.5	9	13	12	13	11	11	13
Median	15	15	13	12	14	14	15	14	13	16
Q3	16	15.5	15	14.5	16	16	16	15	16	16
Max	20	19	20	20	19	20	20	20	20	18

Possible Reasons for the differences between Case 1 and Case 2. Considering all the similarities and differences between Case 1 and Case 2 based on the researcher's observations and student and teacher comments, the possible reasons for the differences between the participation and outcomes of Case 1 and Case 2 are discussed below.

Time Period/ Length of Implementation. Case 1 part was at the beginning of the semester and lasted two months; while Case 2 was at the end of the semester and lasted less than one month. Thus, Case 2 students spent really less time with the online tools than Case 1 students. They had less time to learn the technology, and less time to get used to using online tools in their math class than the Case1 students. Case 1 students also had an advantage since they began using the tools at the beginning of the semester. For Case 2, most of the student grades were already given before the beginning of the implementation of this study.

Teacher B confirms this situation with her answer when I asked her if she saw any effect of using VoiceThread and Google Documents on her students (Case 2) learning. She said:

> I think it was the same as what it would have been regularly. It is at the end of the year, there is not much to learn. If it was at any time of the year, you might have seen some sort of change maybe.

General Differences between Classes in Case 2. Teacher B reported some general differences between her two classes; first period: Online-Tool class; second period: No-Tool class; during the interview. Those differences could be another reason for the different outcomes for Case 1 and Case 2. For example, when I asked her how chapter 10 played out for her students (Case 2); she said:

> I felt the kids understood the purpose of critical path and why it is used and that critical path is the longest path and we need all these activities to finish on time or our project will be delayed. Most students did really well with their projects and picking their topic and creating their own diagraphs. Most of their mistakes were minor or they just left something off.

However when I asked her if there is a difference between the periods in which the different classes were held (Online-Tools and No-Tool classes) in terms of chapter 10, she mentioned some general differences between the two classes and mentioned some advantages that the second period had:

> I think it was not technology versus non-technology. I don't think that had anything to do with it. I think it was more so just the typical difference in the first and second period being the strongest class (2nd period: No-Tool class) and the best time of day. It is still in the morning but it's not first period (Online-Tool class) they aren't all asleep. They're usually on time and attendance isn't an issue. Their projects were probably the best.

Differences between the chapters. (Case2 learned easier chapters than Case1). The chapters that were chosen for AFM (Case 1) and Discrete (Case 2) were different because of the difficulty level. Teachers mentioned that generally they teach higher level concepts in AFM classes than Discrete Math. Thus, they chose easier chapters for Discrete Math classes from the MINDSET curriculum. Most of the students in Case 2 mentioned that the content of the class was so easy, while Case 1 students did not have any similar comments for AFM. This could be another reason for the different outcomes for Case 1 and Case 2. For example, Student TB17 reported that using online tools did not result in any change on his confidence level and he said: "If this was a more difficult course, I would have seen more of a change." When we talked about the simplicity of the chapters and the impacts of online tools on student outcomes with Teacher B (Case2), she said:

> I just feel like… the students didn't really use the tools for their full ability to interact with one another and communicate with one another… I don't know if it would have worked better with different types of problems or questions…definitely more difficult chapter where they could communicate outside of class but I still don't know if this

level of students would use it. The 2nd period (No-Tool class) being the stronger and better class there are probably students that would, but 1st period (Online-Tools class)… being weaker and less motivated as a whole, I don't know if they would.

Separate Discussion Points for RQ2, RQ3 and RQ4.

Research Question 2.

Even if the general differences between Case 1 and Case 2 were discussed above help to make a more informed interpretation of the overall average grade differences for two cases, the reader should consider the small class sizes in this study. Taking even a couple students' grades from the data could change the overall class average. So, the reader should be careful not to make generalizations from these results concerning change on student grades.

In addition to overall average grade differences between the two cases, some differences occurred in the implementation chapters for both Case 1 and Case 2. Various reasons for those differences could affect each case. The possible reasons for those differences among the implementation chapters are discussed below for each case.

Case 1. For the first implementation chapter (Chapter 1), Chapter 3 test, and the decision tree chapter (Chapter 11) quiz, the No-Tool class had a higher average grade than Online-Tools class; while the Online-Tools class had a higher average grade for the other chapters (Figure 5.5)

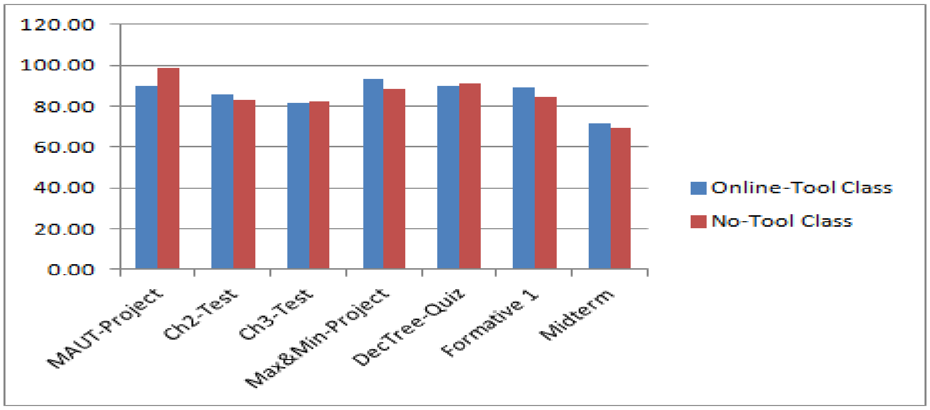


Figure 5.5. Differences are seen among the implementation chapters for the Case 1 Online-Tools class. This figure was given as Figure 4.6 in Chapter 4.

Some possible reasons for those differences among the implementation chapters are discussed in this section. For example, Chapter 1 was the very first chapter in which students were introduced to the online tools, Voice Thread, and Google Documents, and the first assignments were given using the online tools. So, the difference between two classes could be that: Online-Tools class were not used to using communication and collaboration tools and they needed some time to get used to using those tools as a part of their mathematics class. Most of the students reported that they had been using the online tools for the first time in their mathematics class and they were not used to communicating about their problem solutions while solving mathematical problems. Thus, they had a hard time communicating with their teacher through the Voice Thread and with their partners through the Google Document, since both were requiring them to explicitly talk about their thinking about their problem solution. It was observed that a lot of students did not complete their Voice Thread assignments until the due date, and the teacher needed to give students an extension time to complete their Voice Thread homework, which was after the completion of their projects. So, a lot of students could not benefit from the Voice Thread use for the first chapter. After they got used to the tools more, some positive improvement was observed as opposed to the No-Tool class. So, an explanation for the difference between the Online-Tools and No-Tool classes for Chapter 2 could be the effective use of both Voice Thread and Google Document. However we do not see the same effect for Chapter 3. For Chapter 2, students had both Voice Thread homework and a Google Document assignment, but for Chapter 3 they did not have a Voice Thread assignment. Additionally, the teacher visited the student answers for the Voice Thread assignment for Chapter 2 on the day before exam. In this way, she could make clarifications, correct misunderstandings, and also answer student questions just before the exam. A reason for the differences between Chapter 2 and Chapter 3 could be the effective use of student comments on the Voice Thread as a part of face-to-face class. We saw a higher improvement on Online-Tools class' grades for the mini project for Chapter 2 and Chapter 3 than the improvement on their grades for Chapter 2. For Chapter 2 perhaps students only completed the Voice Thread assignment, while for the mini project they also worked through the Google Document. So, they possibly got benefits from using both the Voice Thread and the Google Document for that particular project.

For the decision tree chapter (Chapter 11) quiz, we see a similar situation as with Chapter 2. Even if students completed two homework problems through the Google Documents for this chapter, they did not have any Voice Thread assignment for this chapter. These interesting differences among the outcomes after different uses of online tools imply that both the Voice Thread and Google Documents use were important in their own right to get an increase in student learning.

Case 2. Even if the differences are not too high, for most of the chapters for Case 2 the No-Tool class had a higher average grade than the Online-Tools class as opposed to Case 1 for the implementation chapters. Figure 5.6 below presents the average for Online-Tools and No-Tool classes of Case 2 for each implementation chapter. The most influencing factors for this difference could be the general differences between Case 1 and Case 2 as discussed above; like time period/ length of the implementation and the advantages that the second period (No-Tool class) had over the first period (Online-Tools class) of Case 2. The length of the implementation was too short to allow students to get used to the online tools as a part of their mathematics class and the study was at the end of the semester, so most of the student grades were already given.

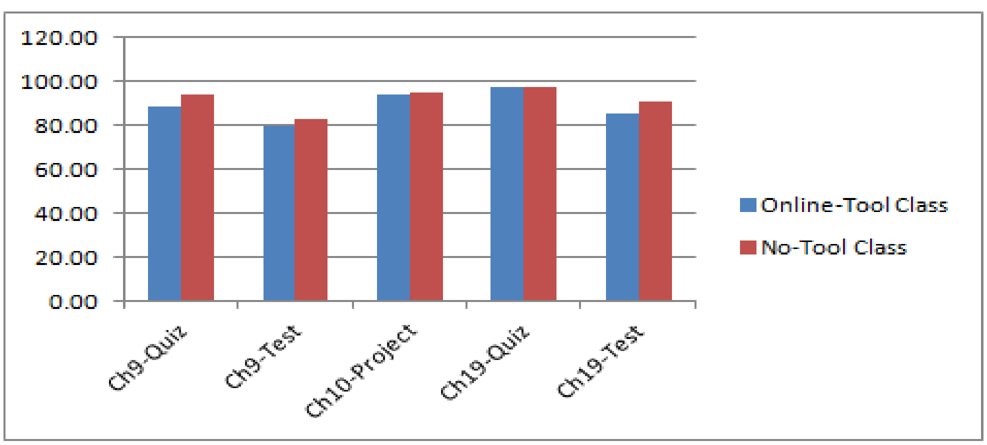


Figure 5. 6. Differences are seen among the implementation chapters for the Case 2 Online-Tools class. This figure was given as Figure 4.8 in Chapter 4.

Dimitriadis (2009) reported *assessment* as among the most essential components of any learning scenario within CSCL environments. However, the students in Case 2 already had received most of their grades before the implementation of this study, so they might be less motivated than the students in Case 1. As discussed above, these negative factors also could be the reason for the lower participation of Case 2 students (see Figure 5.4). At the same time, low student participation might be a factor in the lower student outcomes as well.

Individual's Grades. According to the change on students' grades throughout the semester for Case 1, more than half of the class using online tools had a positive trend effect (not significant) on their grades when we compare the grades of Online-Tools class with the grades of No-Tool class; but there is an percentage of students who did not really benefit from using the tools according to the change in their average grades for implementation versus other chapters. For Case 2, even if there was a higher percentage of Online-Tools students who had higher grades for the implementation chapters than other chapters, we see the same situation for No-Tool class, too. So it is not clear if the positive change in student grades comes only from the impact of using the online tools. It may be that the chapters during the implementation were being easier than the other chapters, since we see the same positive change in grades for the No-Tool class as well.

Qualitative Findings. When we look at the student interviews, 66% of student comments were positive, while 29% of them were negative, and 9% were neutral about using online tools and their impact on their learning. Google Documents were used in this study like a wiki. Reviewed studies suggested wikis as one of the social and effective mobile learning platforms allowing students to create content collaboratively, and evaluate and reflect on each other's work (Duffy and Bruns 2006; Stahl, 2008; Krebs and Ludwig, 2009; Krebs et al., 2010;). The analysis of the interview data suggests that use of Google Documents for problem solving in this study provided students with those opportunities such as those suggested by the literature reviewed. For example, Duffy and Bruns (2006) suggest wikis as an ongoing documentation of student work for research projects; while Stahl (2008) promotes wikis for synchronous math discourse by groups and asynchronous math knowledge building. In this study students worked on mathematics problems as projects. They communicated, collaborated, and co-constructed the solution to the problems. Thus, students used Google Documents in this study not only an ongoing document to keep track of their solutions to mathematics problems; they also built knowledge collaboratively both synchronously and asynchronously. Additionally, most of the students reported that the collaborative platform provided by Google Documents resulted in them having more positive perceptions about the use and impact of online tools in their learning. In conclusion, based on the qualitative data most of the students believe that using online tools in their mathematics class had a positive impact on their learning, but this impact did not result in an increase in their class grades for some of the students.

Research Questions 3 and 4.

According to the demographics of the pre- and post-survey that was presented in the fourth chapter, the student attitudes of Online-Tools classes between pre- and post-survey varied. The changes in the average scores between the pre- and post-survey were not significant for behavioral engagement [BE], mathematics confidence [MC], technology confidence [TC], and attitude to learning mathematics with technology [MT] subscales for both Case 1 and Case 2; but there were some small changes in the median, range, and/or maximum or minimum. For affective engagement [AE] subscale, there was a significant difference between the pre- to post-survey for both Case 1 and Case 2.

Even if we did not see a lot of changes in attitudes, based on the student interviews approximately 60% of the students in the Online-Tools classes had positive attitudes toward using online tools; and about 55% of them felt more confident about mathematics and technology after taking the current class; while 33% of them felt no change in their confidence level, and 5% of the students felt less confident. Combining all these data, quantitative analysis of student attitude based on the quantitative survey represented mixed results; but there was a slight positive trend effect on student attitudes according to the qualitative data. At the same time, it is promising that a lot of students made positive comments about using online tools in their mathematics class. Interestingly, for the affective engagement aspect there was a positive change on student attitudes according to both the quantitative and qualitative data. Since this study was completed with only two Online-Tool classes for a short time period; long term studies on different aspects of student attitudes with multiple classes would help to reveal any possible existing relationships and strengthen any conclusions that could be drawn about the impact of online tools on student attitudes toward mathematics and technology, especially in regard to tools for communication and collaboration

According to the statistical analysis of the attitude pre- and post-survey for the fourth Research question, there were significant and non-significant differences between the Online-Tools and the No-Tool classes for different subscales (see Table 5.3 that was given as Table 4.13 in Chapter 4).

Table 5. 3

The means, standard deviations, p-values and sample for the t- tests for the pre- and post-surveys

N = 75		*M (SD)* pre-survey	*M (SD)* post-survey	Pr > |t|
Whole Scale	Online-Tool	68.59 (10.75)	69.29 (15.42)	0.3533
	No-Tool	66.59 (11.03)	66.59 (10.60)	
BE subscale	Online-Tool	13.76 (3.38)	13.65 (3.26)	0.3375
	No-Tool	13.98 (3.23)	14.12 (2.77)	
TC subscale	Online-Tool	15.32 (2.88)	15.35 (3.73)	0.5401
	No-Tool	14.98 (2.44)	15.22 (2.66)	
MC subscale	Online-Tool	13.03 (3.34)	13.09 (4.61)	0.8274
	No-Tool	12.27 (3.30)	12.20 (3.35)	
AE subscale	Online-Tool	12.00 (3.36)	12.88 (4.00)	**0.0178***
	No-Tool	12.29 (3.35)	11.51 (3.59)	
MT scale	Online-Tool	14.47 (2.94)	14.21 (4.08)	**0.0714**
	No-Tool	13.07 (3.91)	13.54 (3.16)	

Subscales**:** Mathematics confidence [MC], confidence with technology [TC], attitude to learning mathematics with technology [MT], affective engagement [AE], and behavioral engagement [BE].

There is a positive change in the average score for the whole survey for the Online-Tools classes, while the average score of No-Tool classes stayed the same. However, the difference between the means for pre- and post-survey of Online-Tools and No-Tool classes was not significant statistically. This may be because of the large standard deviation for the Online-Tools in comparison to the standard deviation for the No-Tool classes. There are also changes in the average (mean) scores for the subscales between pre- and post-surveys for Online-Tools and No-Tool classes. Even if, the differences between the pre- and post-survey for [BE], [TC], and [MC] subscales were not statistically significant, when we look at the qualitative findings, more than 50% of students reported that their mathematics and technology confidence was higher after using online tools in their mathematics class. Students did not report any information about their behavioral engagement, but as presented in different places in the findings, especially in the first and second research questions, the use of online tools led to some positive behavioral changes for students. For example, students could communicate with their partner and ask questions more easily when they were face-to-face, as opposed to being in the same Google Documents group.

There is a significant difference ($p<.0714$) between the MT (attitude to learning mathematics with technology) subscale results for the Online-Tools and No-Tool classes where the No-Tool classes had a greater mean score on the post-survey than the No-Tool classes. A factor influencing these results could be that the students who had negative attitudes towards the online tools reported extremely low scores for this subscale in the post-survey. Since the number of students in this study was not too large, a few extreme scores can change the average for the whole group. Figure 5.7 presents the comparison of percentages of completely, quite, or fairly confident students for mathematics in general and in current mathematics class (see Figure 4.19 in Chapter 4 for details).

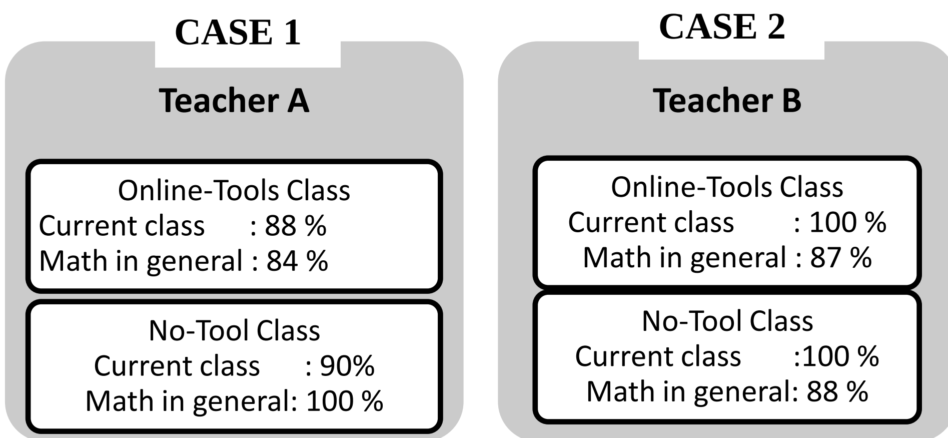


Figure 5. 7. Percentages of completely, quite, or fairly confident students for mathematics in general and in current mathematics class.

As a result, we can reach a conclusion similar to Research question three: Quantitative analysis of student attitudes in Online-Tools and No-Tool classes demonstrated mixed results, but there was a slight positive trend effect on student attitudes for the Online-Tools classes according to qualitative data. For the affective engagement [AE] subscale, there was a significant difference between the Online-Tools and the No-Tool classes according to both quantitative and qualitative data. On the other hand, the relatively low negative change on student attitudes for the Case 1 No-Tool class and the positive change on student attitudes for the Case 2 No-Tool class imply that the structure of the class and the curriculum may also be one of the factors influencing the change in student attitude. So, long term studies examining different aspects of student attitudes with multiple classes and a similar content or curriculum could help to draw more accurate conclusions about the potential impact of online tools on student attitudes for an authentic mathematics curriculum at high school level.

There have been a limited number of studies in the literature about the effects of the use of online tools on student attitude conducted at different grade levels (Garcia and Romero, 2009; Nguyen, Yi-Chuan, and Allen, 2006; Ozel et al., 2008). They report improvement in student attitude when students used online tools. Most of the studies that were investigating effects of online technologies on student attitude applied qualitative instruments. Nguyen, Yi-Chuan, and Allen (2006) had also quantitative instruments, and the quantitative results in their study present statistically non-significant difference between the students who used web-based tools and those who did not use web-based tools. In those studies, online technologies were not used necessarily for combination and collaboration purposes; and other technologies were also used addition to online technologies. For this study the Google Documents was used for communication and collaboration purposes and VoiceThread was used as both a communication and practice tool. Both tools were used completely online. As presented in Chapter 4, and summarized above; for only [AE] (affective engagement) subscale, the difference between the Online-Tools and No-Tool classes for post-survey was statistically significant. For the other subscales, even if there was not a significant difference between the Online-Tools and No-Tool classes; there were variations on the mean, minimum, maximum values; lower and upper quartiles.

The findings of this study present some results revealing the potential of the online tools to improve student attitudes in high school mathematics classes when they are used for communication and collaboration purposes. Even if the quantitative findings of this study had mixed results; qualitative findings demonstrated considerable improvement on student s’ beliefs, feelings, and confidence levels for the majority of students. The findings of this study suggest some of the potential factors responsible the improvements in students' attitudes based on students' own explanations that are presented in Chapter 4.

Implications for Practice

The findings of this study support the idea that using online technologies for communication and collaboration purposes in mathematics classroom in blended form can provide unique opportunities for students to create and communicate their knowledge. According to the results of this study, it could be possible to improve student learning and attitude with the effective use of online tools in mathematics classroom. Below some major points are presented that should be considered by researchers and teachers for the effective use of online technologies in high school mathematics' classrooms.

It takes a significant amount of time after introducing new tools to students and teachers in mathematics classrooms, before they feel comfortable with using the tools in teaching and learning. In this study, only one class period (about 50 min) was set aside for training with Online-Tools classes before beginning the implementation of their use for homework and projects, and about half of the training session was focues on solving technical problems that students had. Approximately 10-15 min. (about 15-20% of a class period) was set aside to solve the technical problems that students had in each class session in which they had some in-class activities using the online tools. Sometimes Online-Tools classes spent less time focusing on the content when compared to the comparison classes. For teachers who plan to use these tools for their classes, it is very important: (a) to train students until they are comfortable using the tools before using them for assignments; and (b) to get technical support, (e.g. such as a technology specialist in the school) who can deal with technical issues and also help to train students in the use of the tools.

The school where this study was conducted had only one internet server available which was did not support some of the features of the Google Documents. Teachers need to be aware of any limitations in the use of the available internet servers in their school so that they can use Google Documents effectively. It would be helpful for a teacher to visit Google's website to get more information about the internet servers and which features they are supported, so that a teacher can be prepared before trying to use those features in school with her/his students.

This study demonstrates that to integrate contemporary methods and tools into the mathematics classroom, teacher support and involvement are crucial. Based on the experiences of the researcher during this study, teachers should learn as much as possible about the tools that they plan to use in their classroom, especially for tools such as VoiceThread and Google Documents Since it is always possible to experience something unexpected during an implementation, it is wise to have a *Plan B* that a teacher can directly move to, if anything does not work or delays occur; since sometimes these technical problems waste a significant amount of time. For example, in this study some students experienced some problems when the whole class was trying to reach their Google Documents at the same time. Sometimes the pages did not open, or the text one student wrote appeared in another place in her/his partner's document. During that time students were working on a homework problem. Students, who had problems with the Google Documents, were asked to type their solution into a Microsoft Word document; so that they would not lose their work. Then, they were asked to try to access Google Documents from home or a convenient place where they have internet access. While they were working outside of the school, students did not report any of the problems that they had in school when they were trying to use the server as a whole class. So, it is important for teachers to be prepared for those types of issues, to avoid frustrate both students and teacher.

As explained in previous chapters, Google Documents were used like a structured-wiki for this study. Even though it was not introduced to them, students used the chat panel a lot to communicate and collaborate with each other for Google Documents assignments. Thus, this study also has implications for educators who plan to use wikis in mathematics classes. Clearly, students see a public space like a wiki or a Google Document as a formal platform. They prefer to use a formal language for their contributions to that platform, and are really careful about what they present there. However, they have a different perception of the chat panel and feel that they have more freedom and flexibility when they use chat. Thus, it is important for instructional designers and educators to consider having or not having a chat panel in their wikis based on their purposes. Readers can visit the discussion for the first Research question for details about students' chat use in this study.

Affordances of the Voice Thread and the Google Documents.

While this study discloses a number of valuable affordances of Voice Thread and Google Documents, additional research is needed to explore the hidden affordances of these two online tools. For example, VoiceThread was not used as a discussion tool in this study; instead it was used as a tool to present the problems. Even when it was suggested to students that they could comment on the slides, students did not communicate with each other through the VoiceThread. The following comment from Teacher B supports this idea to use VoiceThread for open discussions among students: “Maybe it would be good to change some of the due dates and then release what other students said so they could kind of see ‘I said this but somebody else said this, well who’s right’ Then they could use the VoiceThread tool to comment to each other”.

Stahl suggests using students’ public statements in more extended discussions saying: “these (student) public statements are taken up in a social setting and discussed from the multiple perspectives of several participants” which was done with Google Documents in this study (p. 205). Additional research is needed to investigate the use of Voice Thread for expanded purposes to understand the affordances of Voice Thread as a discussion and collaboration tool for mathematical problem solving.

In this study students used spreadsheets in Google Documents for only one project, and the solver piece was not available at the time of the implementation of that chapter. So, students had to download their Google spreadsheet to run the solver. The teacher had to access their work in two steps which took longer. Students set up the problem in Google, then they downloaded it and ran the solver, and digitally drop-boxed it to the teacher. After the implementation of this study, Google added the solver piece to its application. It would be interesting to see if having the solver in the Google spreadsheet would make any difference in the student outcomes.

For this study students did not complete all their assignments in Google Documents. For some assignments they used VoiceThread and they had some paper-pencil homework as well. Since students did not have all assignments in Google Documents, they might not invest adequate time in really learning the tool and using the tool. It would be interesting to conduct a study in mathematics learning where students used Google Documents for every assignment, thereby spending more time learning and using the tool. Increased tool usage and skill on the part of the students might result in more of an effect on student outcomes.

In her comment below, teacher A explained how using the Google Documents was helpful for her as an assessment tool:

> It was easier for me to assess their (student) work, their calculations, did they follow the process; because the way it was set up I could just go down, and say “yes you have this, you did this, you did this... That was like a template that I was able to quickly assess.

Another idea for the future research would be investigating the use of Google Documents as an assessment tool by teachers, and make comparisons with other assessment tools.

Directions for Future Research

The results of this study reveal the potential of online tools to improve student learning and attitude in problem solving when they are used for communication and collaboration purposes in mathematics instruction at the high school level. The following recommendations should be considered by researchers for future studies:

- Effective student and teacher training are two essential factors for obtaining improvement in student learning and attitude in mathematics classes at the high school level. So, any use of online tools for communication and collaboration purposes should provide adequate training time and practice opportunities for students and teachers.
- A longitudinal study with a larger number of participants and a study design with tighter controls would provide more generalizable conclusions in terms of the potential impacts of online tools on student learning and attitude in high school mathematics classes.
- More synchronous use of online tools would increase the number of student who benefit from the opportunities that were provided by the emerging online technologies, because students have different approaches to online communication. Some students prefer more immediate feedback on their work and immediate response to their questions.
- This study incorporated the innovative idea of using online tools as a part of face-to-face instruction (blended form) in the mathematics classroom. The design of future studies using online technologies should include a combination of online activities with in-class interactions so that the advantages of online communication and face-to-face interaction are both included.

- The results of this study demonstrate that the use of online technologies in high school mathematics does not necessarily improve student outcomes. Individual differences among students might be a crucial element in ensuring that students gain benefits from using online technologies. A future study focusing on determining if learner characteristics influence the effectiveness of using online tools in mathematics classes would shed new light on understanding best practices for use of the tools.
- One of the significant findings of this study is recognition of the difference that exists between the use of online tools for collaborative and cooperative student work in high school mathematics problem solving. Future research should identify how and why students approach mathematical problem solving from a collaborative or cooperative perspective. What are the influential factors that emerge during that process? For example, one factor identified in this study that seemed to influence the effectiveness of the tool usage was the structure of the mathematical problems. Sometimes the way a problem is structured requires collaborative work and sometimes it requires cooperative work for a more effective solution.
- The sample used in this study consisted of high school students who were in the adolescence years (12-18) (Erikson, 1979). Development psychology suggests that in this adolescence period children are exploring their independence and developing a personal identity (Erikson, 1979). During this identity seeking period children's social relations are really important. So, they could be sensitive about their relationships and interactions with their peers. In this sense, the stage of psychological development of

the participants could have impacted their participation and communication in the assignments with the online tools. For online tool assignments students were asked to put their mathematical thinking into words and share them with their peers publicly. For example, some students did not participate in the Google assignments in this study. It could be because they were worried about writing something wrong and thereby being criticized by another group member. Future studies should consider the stage of psychological development of students' and how that might influence students' reactions and participation in the use of online communication and collaboration tools.

Conclusions

Use and development of contemporary tools has always been a challenge for educators. Computer Supported Collaborative Learning research specifically focuses on employing communication and collaboration technologies in educational settings effectively. This study provides an understanding of the integration process of online communication and collaboration tools into an authentic mathematics curriculum. Specifically, this study helped to conceptualize the implementation of two online tools, VoiceThread and Google Documents, into modeling problem solving in a blended form.

Use of different types of information technologies can have positive impacts on student learning and engagement with the content (Garcia and Romero, 2009; Krebs et al., 2010; Nguyen et al., 2006; Oliver, 2008; Ozel et al., 2008). In this study, positive impacts of online technologies were observed in regards to student learning and attitudes for the majority of the students. A lower percentage of students had negative perceptions and/or attitudes towards online tools, or their grades did not show a positive increase when they used online tools. These results imply that individual differences among students may be a factor in terms of the impact of using online tools in learning high school mathematics. Clearly, diverse instructional methods and tools should be a part of students' school experience for mathematics learning, so that the school can address more students' needs regardless of personal learning styles and preferences. The findings of this study demonstrate that some students were not willing to replace existing mathematics learning and studying habits with the use of online tools; but most of the students were willing to use online tools by blending them with their existing learning and studying habits. The blending here means to continue regular teaching methods in the classroom, while integrating online tools into the teaching and learning process using them for homework and projects.

The theoretical aspects of this study resulted in combining two existing theories -- the social-knowledge building model by Stahl and an online learning theory by Anderson – into one Modified framework. This study suggests a Modified framework for analyzing student-student interaction, communication, and collaboration in a blended mode of mathematics instruction. The use of online technologies for mathematics in blended form revealed that: (a) the social-knowledge building process using online tools is directly related to students' personal understanding as suggested by Stahl, (b) the social-knowledge building process (problem solution) can occur either in a collaborative or cooperative form in a blended mode depending on the structure of the problem, (c) others' public statements may have directs impacts on students' personal comprehension, (d) student-teacher and student-content interactions have direct influences on student-student interaction as suggested by Anderson, and (e) student-teacher and student-content interactions also directly influence both social-knowledge building and personal-understanding processes.

Even if this study was completed in a short period of time with some limitations, the qualitative findings of this study suggest that using online technologies for communication and collaboration purposes might have the potential to enhance student learning and influence the development of positive attitudes in learning high school mathematics. Although quantitative impacts were mixed, a majority of the students demonstrated positive attitudes towards using online tools for problem solving and had positive perceptions about the impacts of using online tools on their learning. Students also exhibited positive attitudes towards the integration of online tools with face-to-face instruction. They mentioned this was a unique experience for them in terms of learning mathematics with online technology. Some of them reported that they plan to use Google Documents for their other classes and in college. In this case, it is really important to provide high school students with the experience of using online communication and collaboration tools for learning mathematics early before they enter the college classroom.

REFERENCES

Anderson, T. (2003). Modes of interaction in distance education: Recent developments and research questions. In M. Moore (Ed.) *Handbook of Distance Education.* (p. 129-144). Mahwah, NJ.: Erlbaum.

Anderson,T. (2008). Towards a Theory of Online Learning. In T. Anderson, T. (Eds.), *Theory and Practice of Online Learning*. (pp. 45-75). Edmonton, AB: Athabasca University, AU Press.

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning, 7,* 245–274.

Artigue, M. (2007). Digital technologies: a window on theoretical issues in mathematics education. In: *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education, Larnaca, Cyprus.*

Baker, E. L. & Mayer, R. E. (1999). Computer-based assessment of problem-solving. *Computers in Human Behavior, 15,* 2692–82.

Bandura, A. (1977). *Social learning theory.* Morristown, NJ: General Learning Press.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliff, NJ: Prentice-Hall.

Bandura, A. (1991). Social cognitive theory of self-regulation, *Organizational Behavior and Human Performance. 50,* 2482–87.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: W.H. Freeman.

Beatty, R., & Geiger, V. (2010). Technology, communication, and collaboration: re-thinking communities of inquiry, learning, and practice. 251–284. In Hoyles, C., & Lagrange, J.-B. (Eds.) (2010). *Mathematics education and technology-rethinking the terrain. The 17th ICMI study.* Heidelberg, New York: Springer.

Beatty, R., & Moss, J. (2006). Connecting grade 4 students from diverse urban classrooms: virtual collaboration to solve generalizing problems. In C. Hoyles, J. –B. Lagrange, L. H. Son, & N. Sinclair (Eds.), *Proceedings of the Seventeenth Study Conference of the International Commission on Mathematical Instruction.* Hanoi Institute of Technology and Didirem Universite Paris 7.

Biggs, J. B. (1989). Approaches to the enhancement of tertiary teaching. *Higher Education Research and Development, 8*(1), 72–5.

Blau, I., & Caspi, A. (2009). Sharing and collaborating with Google Docs: the influence of psychological ownership, responsibility, and student's attitudes on outcome quality. In T. Bastiaens et al. (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2009* (pp. 33293–335). Chesapeake, VA: AACE. Retrieved from: http://www.editlib.org/p/32961.

Bogdan, R C. & Biklen, S. K. (2007). *Qualitative research for education: an introduction to theory and methods,' 2nd* edition. Boston: Allyn and Bacon.

Bonk, C. J. & Graham, C. R. (2006). *Handbook of blended learning: global perspectives, local designs*. San Francisco, CA: Pfeiffer Publishing.

Brown, A. L., Ellery, S., & Campione, J. C. (1998). Creating zones of proximal development electronically. In J. G. Greeno & S.V. Goldman (Eds.), *Thinking practices in mathematics and science learning,* (pp. 341–367).

Bruns, A., Humphreys, S. (2005). Wikis in teaching and assessment: The M/Cyclopedia project. *Proceedings of the 2005 International Symposium on Wikis,* (pp. 25–32) San Diego, CA.

Catley, A. (2003). Using autography in Tynemouth College. *Micro Math, 9*(2), 25–29.

Chalmers, C. (2009). Primary students' group metacognitive processes in a computer supported collaborative learning environment (Doctoral dissertation).

Clements, D. H. & Sarama, J. (2005). Young children and technology: what's appropriate. In W. J. Masalski & P. C. Elliott (2005). *Technology-Supported Mathematics Learning* (pp.51–74). Reston, VA: National Council of Teachers of Mathematics.

Conner, N. (2008). *Google Apps: The missing manual*. O'Reilly Media.

Creswell, J. W. & Plano-Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Crook, C. (1994). *Computers and the Collaborative Experience of Learning*. London: Routledge.

Cubric M., (2007). Wiki-based process framework for blended learning. *Proceedings of the 2007 International Symposium on Wikis (WikiSym'07),* (pp. 11–24), ACM, 2007.

Dance, F. E. X. (1970). The "concept" of communication. *The Journal of Communication,* 20(June), 201-210.

Deaney, R., Ruthven, K., & Hennessy, S. (2003). Pupil perspectives on the contribution of information and communication technology to teaching and learning in the secondary school. *Research Papers in Education*, *18*(2), 1411–65.

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning: from design to orchestration. To appear in Kaleidoscope Legacy Book.

Duffy, P., & Bruns, A. (2006). The use of blogs, wikis and RSS in education: a conversation of possibilities. *Proceedings Online Learning and Teaching Conference*, (pp. 313–8), Brisbane.

Educause Learning Initiative (2008). *7 things you should know about Google Apps*. Retrieved October 1, 2010, from http://net.educause.edu/ir/library/pdf/ELI7035.pdf

Eppler M (2006) A comparison between concept maps, mind maps, conceptual diagrams, and visual methaphors as complementary tools for knowledge construction and sharing. *Information Visualization*, 5, 202-210.

Fischer, F., Kollar, I., Mandl, H., & Haake, JM (2007). *Scripting computer-supported collaborative learning–cognitive, computational, and educational perspectives*. New York: Springer.

Galbraith, P., & Haines, C. (1998). Disentangling the nexus: attitudes to mathematics and technology in a computer learning environment. *Educational Studies in Mathematics*, *36*, 275–290.

Galegher, J., Kraut, R. E., & Egido, C. (1990). *Intellectual teamwork: social and technological foundations of cooperative work (*pp. 1–20). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gao & Sun. (2010). Supporting an online community of inquiry using VoiceThread. In C. Maddux, et al. (Eds.) *Research Highlights in Information Technology and Teacher Education*. 2010. (pp. 91–8). Chesapeake, VA: Society for Information Technology and Teacher Education (SITE).

Garcia, M. D. M. & Romero, I. M. (2009). The influence of new technologies on learning and attitudes in mathematics in secondary students. *Electronic Journal of Research in Educational Psychology, 17*(7), 369–396.

Glesne, C. (1999). *Becoming qualitative researchers.* 2nd edition. White Plains: Longman Publishers.

Goos, M., Cretchley, P. (2004) Computers and the Internet in mathematics education. In *Research in Mathematics Education in Australia 2000-2003*, Post Pressed, Flaxton, 151–174.

Graham, C. R. (2006). Blended learning systems: Definition, current trends, and future directions. In C.J. Bonk & C.R. Graham (Eds.), *Handbook of blended learning: Global perspectives, local designs*, (pp. 3–21). San Francisco, CA: Pfeiffer Publishing.

Graham, J., & Hodgson, T. (2008). Speaking math. *Learning & Leading with Technology, 35*(5), 24–27.

Greenberg, S. (Ed.). (1991). *Computer-supported cooperative work and groupware*. New York: Academic Press.

Gress, M. F., Hadwin, A., & Winne, P. (2010). Measurement and assessment in computer-supported collaborative learning. *Computers in Human Behavior*, *26*, 80–6814.

Grudin, J. (1994). Computer supported collaborative work: its history and participation. *IEEE Computer*, *27*, 19–26.

Guin, D.; Trouche, L. (1999): The complex process of converting tools into mathematical instruments: the case of calculators. *International Journal of Computers for Mathematical Learning*, *3*, 195–227.

Guzdial, M., & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *Journal of the Learning Sciences*, *9*, 437–469.

Hadwin, A.F., Winne, P.H., & Nespit, J. C. (2005). Roles for software technologies in advancing research and theory in educational psychology. *British Journal of Educational Psychology*, *75*, 1–24.

Hannula, M. S. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics*, *49*, 25–46.

Hekimoglu S., & Kittrel, E. (2010). Challenging students' beliefs about mathematics: The use of documentary to alter perceptions of efficacy. *PRIMUS: Problems, Resources, and Issues in Mathematics Undergraduate Studies*, 1935–4053, *20*(4), 299–331.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies, 37*, 155–192.

Hodley, C., & Linn, M. (2000). Teaching science through online peer discussions: speak easy in the knowledge integration environment. *Journal of Science Teaching, 22*, 839–857.

Holcomb, L. B., & Beal, C. M. (2010). Capitalizing on web 2.0 in the social studies context. *TechTrends*, *54* (4), 28–32.

Hoyles, C., & Lagrange, J.-B. (Eds.). (2010). Mathematics Education and Technology-Rethinking the Terrain. *The 17th ICMI Study*. Heidelberg, New York: Springer.

Hoyles, C., Kalas, I., Trouche, L., Hivon, L., Noss, R., & Wilensky, U. (2010). Connectivity and virtual networks for learning. 439–462. In Hoyles, C., & Lagrange, J.-B. (Eds.). (2010). Mathematics Education and Technology-Rethinking the Terrain. *The 17th ICMI Study*. Heidelberg, New York: Springer.

Hoyles, C., Wolf, A., Molyneux-Hodgson, S., & Kent, P. (2002). Mathematical skills in the workplace: final report to the Science, Technology and Mathematics Council. Institute of Education, London.

Isiksal, M., & Askar, P. (2005) The effect of spreadsheet and dynamic geometry software on the achievement and self-efficacy of 7th-grade students, *Educational Research*, *47*(3), 333–350.

Järvenoja, H., & Järvelä, S. (2005). How students describe the sources of their emotional and motivational experiences during the learning process: a qualitative approach. *Learning & Instruction, 15*, 465–480.

Kaput, J. J., & Thompson, P. W. (1994). Technology in mathematics education research: the first 25 years. In *JRME*: *Journal for Research in Mathematics Education, 25*(6), 676–684.

Kariuki, P., & Paula, W. (2002, November). *The effects of motivation on at risk high school students in math performance.* Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Chattanooga, TN.

Karpicke, J. D., Roediger H. L. (2008). The critical importance of retrieval for learning. *Science.* 319(5865), 966–968.

Kee, K. L., & Sam, L. C. (2006). The impact of the use of graphics calculator on the learning of statistics: a Malaysian experience. *Proceedings of the Seventeenth ICMI Conference "Technology Revisited"*, 288–294.

Kirschner, P. A., Martens, R. L., & Strijbos, J. W. (2004). CSCL in higher education? A framework for designing multiple collaborative learning environments. In J. W., Strijbos, P. A. Kirschner, R. L., Martens (Eds.), *What we know about CSCL: And implementing in higher education*, (pp. 3–30). Boston, MA: Kluwer.

Koschmann, T.(2002). Dewey's contribution to the foundations of CSCL research. Paper presented at the Computer Support for Collaborative Learning, 2002, Boulder, CO.

Kramarski, B. (2006). What can be learned from metacognitive guidance in mathematical online discussion? In C. Hoyles, J. –B. Lagrange, L. H. Son, & N. Sinclair (Eds.), *Proceedings of the Seventeenth Study Conference of the International Commission on Mathematical Instruction.* Hanoi Institute of Technology and Didirem Universite Paris 7.

Krebs, M., Ludwig, M. (2009). Math learning with wikis. Paper presented at the 9th International Conference on Technology in Mathematics Teaching (ICTMT 9), Metz (2009), Retrieved from http://www.ictmt9.org/contribution.php?id=84&lang=en.

Krebs, M., Ludwig, M., & Müller, W. (2010). Learning mathematics using a wiki. *Procedia - Social and Behavioral Sciences, 2*(2), 1469–1476.

Krebs, M., Schmidt, C., Henninger, M., Ludwig, M., & Müller, W. (2010). Are wikis and weblogs an appropriate approach to foster collaboration, reflection and students' motivation? In N. Reynolds and M. Turcsányi-Szabó (Eds.), *KCKS 2010, IFIP AICT 324* (pp. 200–209).

Laborde, C., & Stra¨ßer, R. (2009). Place and use of new technology in the teaching of mathematics: ICMI activities in the past 25 years. *ZDM Mathematics Education, 42*, 121–133. doi: 10.1007/s11858-009-0219-z.

Lehtinen, E. (2003). Computer supported collaborative learning: An approach to powerful learning environments. In E. De Corte, L. Verschaffel, N. Entwistle, & J. van Merriëboer, *Unravelling basic components and dimensions of powerful learning environments*. New York: Pergamon Press.

Lipponen, L. (2002). Exploring foundations for computer-supported collaborative learning. In G. Stahl (Ed.), *Computer support for collaborative learning: foundations for a CSCL community.* Proceedings of the Computer-supported Collaborative Learning 2002 Conference (pp. 72–81). Hillsdale, NJ: Erlbaum.

Lipponen, L., Hakkarainen, K., & Paavola, S. (2004). Practices and orientations of CSCL. In J. W., Strijbos, P. A., Kirschner, & R. L., Martens (Eds.), *What we know about CSCL: And implementing in higher education*, (pp. 3–30). Boston, MA: Kluwer.

Lipponen, L., Rahikainen, M., Hakkarainen, K., & Palonen, T. (2002). Effective participation and discourse through a computer network: Investigating elementary students' computer-supported interaction. *Journal of Educational Computing Research, 27*, 353–382.

Littlejohn, S. W., & Foss, K. A., (2008). *Theories of human communication* (9th ed.). Belmont, CA: Thompson Wadsworth.

Lombardi, M. (2007). Authentic learning for the 21stCentury: An overview. *EDUCAUSE Learning Initiative.* Retrieved October 24, 2011 from: http://connect.educause.edu/library/abstract/AuthenticLearning for/39343

McKenzie, A. D., Morgan, C. K., Cochrane, K. W., Watson, G. K., & Roberts, D. W. (2002). Authentic learning: What is it, and what are the ideal curriculum conditions to cultivate it in? In A. Goody, J. Herrington & M. Northcote (Eds.), *Quality Conversations: Proceedings of the 2002 Annual International Conference of the Higher Education Research and Development Society of Australasia (HERDSA)* (pp.

426-433). Perth, Western Australia: Higher Education Research and Development Society of Australasia.

Merriam, S. (1995). What can you tell from an N of 1?: Issues of validity and reliability in qualitative research. *PAACE Journal of Lifelong Learning, 4*, 51–60.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousands Oak, London New Delhi: Sage.

Moynahan, E. O. (1973). The development of knowledge concerning the effects of categorization upon free recall. *Child Development, 44*, 238–245.

Nguyen, D M., Yi-Chuan J. H., & Allen, D. (2006).The impact of web-based assessment and practice on students' mathematic learning attitudes. *Journal of Computers in Mathematic & Science Teaching*, *25*(3), 251–279.

Ocker, R. J., & Yaverbaum, G. J. (1999). Asynchronous computer-mediated communication versus face-to-face collaboration: results on student learning, quality and satisfaction. *Group Decision and Negotiation, 8*, 427–440.

Oliver, M. (2008). *Developmental mathematics: a study of student experiences*. (Doctoral dissertation). Retrieved from UMI. (3320690).

Osguthorpe, R. T., & Graham, CR (2003). Blended learning environments: definitions and directions. *The Quarterly Review of Distance Education, 4*(3), 227–233.

Ozel, S., Yetkiner, Z. E., & Capraro, R. M. (2008). Technology in K-12 mathematics classrooms.*School Science and Mathematics, 108*(2), 80–85.

Pape, L. (2010). Blended teaching & learning: developing courses that combine face-to-face and virtual instruction in pursuit of 21st-century skills in classroom. *The School Administrator*, *4*(67), 16–21.

Peressini, D. D., & Knuth, E. J. (2005). The role of technology in representing mathematical problem situations and concepts. In W. J. Masalski & P. C. Elliott (2005). *Technology-Supported Mathematics Learning*, (pp.277–290). Reston, VA: National Council of Teachers of Mathematics.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education*, *48*, 285–300.

Reed, H. C., Drijvers, P., & Kirschner, P. A. (2010). Effects of attitudes and behaviors on learning mathematics with computer tools. *Computers & Education*, *55*, 1–15.

Resta, P., & Laferrière, T. (2007). Technology in support of collaborative learning. *Educational Psychology Review*, *19*(1), 65–83.

Roschelle, J., & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed.), *Computer supported collaborative learning* (pp. 69–197). Berlin Heidelberg New York: Springer.

Ruffell, M., Mason, J., & Allen, B. (1998). Studying attitude to mathematics. *Educational Studies in Mathematics*, *35*, 1–18.

Scardamalia, M., Bereiter, C., & Lamon, M. (1994). The CSILE project: trying to bring the classroom into world 3. In K. McGilly (Ed.), *Classroom Lesson: Integrating Cognitive Theory & Classroom Practice*, (pp. 201-228). Cambridge, MA: MIT Press.

Schraw, G., Crippen, K.J., & Hartley, K. (2006). Promoting Self-Regulation in Science Education: Metacognition as Part of a Broader Perspective on Learning. *Research in Science Education*, 36, 111–139.

Sims, R. (1999). Interactivity on stage: Strategies for learner-designer communication. *Australian Journal of Educational Technology*, 15(3), 257-272. http://www.ascilite.org.au/ajet/ajet15/sims.html

Smith, A. 2004. *Making Mathematics Count*. London: The Stationary Office.

So, H. J., & Bonk, C. J. (2010). Examining the roles of blended learning approaches in computer-supported collaborative learning (CSCL) environments: a Delphi study. *Educational Technology & Society*, *13*(3), 189–200.

So, H. J. (2009). When groups decide to use asynchronous online discussions: collaborative learning and social presence under voluntary participation structure. *Journal of Computer Assisted Learning*, *25*(2), 143–160.

Stahl, G. (2006). *Group cognition: computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.

Stahl, G. (2008). *Integrating a wiki into support for group cognition.* Paper presented at the International Conference of the Learning Sciences (ICLS 2008), Utrecht, Netherlands. Retrieved from http://GerryStahl.net/pub/icls2008wiki.pdf.

Stahl, G. (2010). Computer mediation of collaborative mathematical exploration. In B. Schwarz (Chair), *Social construction of mathematical meaning through collaboration and argumentation.* Symposium conducted at the meeting of the ICLS 2010.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Taylor, R. (Ed.). (1981). *The computer in the school: tutor, tool, tutee.* New York: Teachers College Press.

Ursini, S., & Sacristán, A. I. (2006). On the role and aim of digital technologies for mathematical learning: Experiences and reflections derived from the implementation of computational technologies in Mexican mathematics classrooms. *Proceedings of the Seventeenth ICMI Study Conference "Technology Revisited",* 477–487.

Vygotsky, L.S. (1962). *Thought and language* (E. Hamsman & G. Vankan, Eds., Trans.). Cambridge, MA: MIT Press.

Vygotsky, L.S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wagner, E.D. (1994). In support of a functional definition of interaction. *American Journal of Distance Education*, *8*(2), 6 – 26.

Wei, C. , Maust B. , Barrick, J., Cuddihy E., and Spyridaki, J. H. (2005). Wikis for supporting distributed collaborative writing. *Proceedings of the Society for Technical Communication 52nd Annual Conference*, Seattle.

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education*, *46*, 71–95.

Weinberger, A., Stegmann, K., & Fischer, F. (2010). Learning to argue online: Scripted groups surpass individuals (unscripted groups do not). *Computers in Human Behavior*, *26*, 506–515.

Willis, S., & Kissane, B. (1989). Computer technology and teacher education in mathematics. In *Department of Employment, Education and Training, Discipline review of teacher education in mathematics and science.* Canberra: Australian Government Publishing Service, 6, 57–92.

Yin, R. (2003). *Case study research: Design and methods.* 3rd edition. Thousand Oaks, CA: Sage.

APPENDICES

APPENDIX A

MINDSET Project Student Informed Consent Form

Student Informed Consent Form for Research

North Carolina State University

This form is valid November 3, 2010 to November 3, 2011

Primary Investigator: Dr. Karen Keene

What are some general things you should know about this research study?

You are invited to volunteer to participate in an educational research project. The purpose of this project is to learn more about student' abilities to do multi-step problem solving and about how students perceive mathematics in fourth year high school math classes.

What will happen if you take part in the study?

If you agree to participate in this study, you will be asked to complete an assessment to the best of your ability, taking approximately 60 minutes of class time at the beginning and end of the semester. If you choose not to participate in this study, you will be asked to complete the assessments but your results will not be included in analysis done by the research team. In addition, you may be asked to have a member of the research team interview you. These interviews will be used by the research team to better understand your thoughts, feelings, and knowledge about your mathematics course. The interview will take approximately 45 minutes and will take place after school or during one of your free periods. Interviews may be videotaped and your comments may be transcribed for publication (identity withheld).

These videos will be stored on a secure server and will be destroyed five years after the completion of the study with the exception of any data used in publications.

A member of the research team may also come in to observe your classroom. During observations, the observer will take field notes, and these observations will be used for the research team to gather information about teachers' instructional choices in the classroom. Observations may be videotaped for research purposes. The camera will be placed in the back of the room with the main focus on the teacher. The videotapes will be utilized mostly for the verbal discussions; however, the research team may present a clip of a video during research presentations or may use an image in a publication.

You will also be asked to complete surveys and questionnaires describing your experiences learning mathematics. Surveys and questionnaires will take 10-15 to complete and will ask you about your thoughts, feelings, and knowledge about your mathematics course. All data and notes will be stored in a locked file cabinet at the Friday Institute and will be destroyed five years after the completion of the study, with the exception of any data used in publications. If any of your data is used in future research publications or presentations, you will not be identified by name.

Risks and Benefits

There will be no risk associated with your participation in the research study. If you are in a classroom where this new curriculum is being implemented, your teacher will devote up to one entire semester teaching from these materials. You will not lose knowledge from what would have been taught in their standard curriculum.

You will benefit from learning the material your teacher is using because the curriculum was designed with the hope that students who use the materials will gain multi-step problem-solving skills and have more positive attitudes towards mathematics. However, you will receive no benefit from participating in the evaluation of the curriculum project.

The knowledge the researchers gain from your experiences will add to the knowledge base in mathematics education, especially with regard to how teachers can learn a new content area and pass this knowledge on to their students.

The activities you are being asked to perform for this research study will not be graded and therefore will not affect your final grade in this class.

Confidentiality

The information and data derived from the assessments, surveys, videotapes and observations will be kept strictly confidential. It will be stored securely in a locked file and will be made available to the research team to use for research, presentation, and publication purposes only. No reference will be made to your name either in oral or written reports and transcripts that could link you individually to the study. To keep your identity confidential, all students will be identified by a random number. We will use a master list with codes which will replace names to the study data we collect. This master list will be kept in a locked file cabinet at the Friday Institute. The audio or videotapes will be digitally recorded and stored on a secure server at the Friday Institute. The files will be destroyed five years after the completion of the study, with the exception of any data used in publications.

Compensation

You will receive no payment for your participation in this research study, and there are no foreseeable costs for you associated with your participation.

What if you have questions about this study?

If you have any questions at any time, you may contact Dr. Karen A. Keene at 919-513-3374. Her address is 502J Poe Hall, NC State University. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919-515-4514), or Carol Mickelson, IRB Coordinator, Box 7514 NCSU Campus (919-515-7515).

Participation

Your participation in this study is voluntary; you may decline to participate without penalty. Your participation, or lack thereof, will not affect your grades or standing in your class. If you decide to participate, you may withdraw from the study at any time without penalty. If you withdraw from the study before data collection is complete your data will be returned to you or destroyed at your request.

Please initial by the statements that apply to you.

_____ I have read and understood the above information.

_____ I give permission to the MINDSET project team and North Carolina State University to make audio-video recordings of me during classroom instruction. I understand that the video recording will be used as a record of the lesson and the discussion taking place and may be used for publication and presentation purposes.

_____ I further consent that a transcript of the audio-video recording of the classroom observation can be made.

_____ I will allow personnel from the MINDSET project team to interview me.

_____ I give permission to the MINDSET project team and North Carolina State University to make audio-video recordings of me during the interview. I understand that the video recording will be used as a record of the interview and the discussion taking place and may be used for publication and presentation purposes.

_____ I further consent that a transcript of the audio-video recording of the interview can be made.

_____ I will allow personnel from the MINDSET project team to send me surveys and questionnaires used to describe my learning experiences that I will complete to the best of my ability.

_____ I will complete the surveys and assessments to the best of my ability. I understand that these surveys and assessments will not count towards my grades or standing in this class.

By signing below, I am giving the project team and NC State permission to use those items initialed above for record keeping and research purposes.

If the student is under 18 years of age we are asking for the parent/guardian to also sign this form and confirm that they agree to have the minor participate in the research study.

______________________________	______________________________
Printed Full Name of Student	Printed Full Name of Parent/Guardian
______________________________	______________________________
Student's Signature	Signature of Parent/Guardian
______________Date________________	______________Date____________

APPENDIX B

IRB- North Carolina State University

IRB# 1692

North Carolina State University

Institutional Review Board for the Use of Human Subjects in Research

SUBMISSION FOR NEW STUDIES

GENERAL INFORMATION

1. **Date Submitted:** *8-25-10* 1a. **Revised Date:** _____
2. **Title of Project:** *Mathematics Instruction using Decision Science and Engineering Tools (MINDSET)*
3. **Principal Investigator:** *Karen Keene, PhD;*
4. **Department:** *Math Science and Technology Education*
5. **Campus Box Number:** *7801*
6. **Email:** *Karen_keene@ncsu.edu*
7. **Phone Number:** *513-3374*
8. **Fax Number:** _____
9. **Faculty Sponsor Name and Email Address if Student Submission:** _____
10. **Source of Funding? (required information):** *NSF*
11. **Is this research receiving federal funding?:** *yes*

12. **If Externally funded, include sponsor name and university account number:** *<u>NSF, Acct# 527944,534488</u>*
13. **RANK:** ☒ Faculty ☐ Student: ☐Undergraduate; ☐ Masters; or ☐PhD ☐ Other (specify): _____

As the principal investigator, my signature testifies that I have read and understood the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.

Principal Investigator:

<u>Karen Keene, PhD</u> ____* _____

(typed/printed name) (signature) (date)

As the faculty sponsor, my signature testifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the ***principal investigator of record****.*

APPENDIX C

IRB- Wake County School System

WAKE COUNTY
PUBLIC SCHOOL SYSTEM

EVALUATION AND RESEARCH

3600 WAKE FOREST ROAD
RALEIGH, NORTH CAROLINA 27609
PHONE: 919.850.1863
FAX: 919.850.1861

March 7, 2011

Karen Keene
PO Box 7801
North Carolina State University
Raleigh, NC 27695

RE: **Project No. 797**

Dear Dr. Keene:

Your request to conduct research entitled "MINDSET (Mathematics Instruction Using Decision Science and Engineering Tools)" in Wake County Schools has been approved.

Please provide a copy of this approval letter to each principal and teacher when soliciting their participation. Although this letter constitutes our office's approval of your study, it does in no way obligate a school to participate; it is up to them to make that decision. If there are questions about this constraint, please call me at 850-1798.

I look forward to working with you and learning the results of your study. Please remember to send me a summary of your findings once your study is completed.

Sincerely,

Angie Wright

Angie Wright, Ed.D.
Chair, Research Review Committee
Evaluation & Research Department
850-1798

WEBSITE: WWW.WCPSS.NET

APPENDIX D

MINDSET Project Teacher Informed Consent Form

Teacher Informed Consent Form for Research

North Carolina State University

This form is valid November 3, 2010 to November 3, 2011

Primary Investigator: Dr. Karen Keene

What are some general things you should know about this research study?

You are invited to volunteer to participate in an educational research project. Mathematics INstruction using Decision Science and Engineering Tools (MINDSET) is a project to create, implement and evaluate a new curriculum to teach standard math concepts using math-based decision making tools in fourth year high school classrooms. Currently we are pilot testing the curriculum in some classrooms with the idea that eventually it will be adopted as a curriculum. The purpose of this research is to evaluate the curriculum by conducting qualitative research in the classes that are using the curriculum, and doing a large scale assessment of problem solving skills and attitudes towards mathematics in many fourth year classrooms across the United States. This research will support the development of an important new high school mathematics course that will be implemented nationwide. The assessment will provide information to evaluate and improve the course and help us learn about high school students' problem solving skills.

What will happen if you take part in the study?

If you agree to participate in this study, you will be asked to first give a consent form to each student in your class. The consent forms will be sent to you approximately two weeks before the assessment and will be collected along with the assessments. Next, you will give an assessment to your students, taking approximately 120 minutes of class time. This involves 60 minutes at the beginning and 60 minutes at the end of the class.

In addition, you may be asked to have a member of the research team interview you and/or observe one or more lessons in your classroom. You will be told in advance if a researcher would like to visit your classroom. During observations, the observer will take field notes, and these observations will be used for the research team to gather information about teachers' instructional choices in the classroom. Observations may be videotaped for research purposes. If you give consent to being videotaped, the camera will be placed in the back of the room with the main focus on you, the teacher. The videotapes will be utilized mostly for the verbal discussions; however, the research team may present a clip of a video during research presentations or may use an image in a publication.

Interviews will be used to learn about your experiences with the MINDSET materials and the summer workshop. Interviews will take approximately 45 minutes. Interviews may be videotaped and your comments may be transcribed for publication (identity withheld).

All videos will be stored on a secure server and will be destroyed five years after the completion of the study, except for any portions of the videos that are used in publications.

You may also be asked to complete surveys, logs, feedback forms, and implementation journals describing your experiences teaching the new materials. Each of these surveys will take approximately10-15 minutes to complete and will ask you about your experience with the summer workshop, about your instructional methods, and about your perceptions regarding your teacher qualifications. Each lesson log will take approximately 10-15 minutes to complete and will ask you information about your implementation of certain lessons. Feedback forms will take 1-2 hours per chapter to complete and will ask you about how you implemented the MINDSET materials in your classroom. Journals will take approximately 20 minutes to complete each entry, where you detail you instructional choices and your thoughts and feelings towards the materials. All together, you will spend approximately 8-10 hours of out of school time working with this evaluation. All data and notes will be stored in a locked file cabinet at the Friday Institute and will be destroyed five years after the completion of the study, with the exception of any data used in publications. If any of your data is used in future research publications or presentations, you will not be identified by name.

Risks and Benefits

There will be no risk associated with your participation in the research study.

You will benefit from teaching the MINDSET material because the materials bring in interesting, real-life examples to motivate student learning but there is no benefit from participating in the evaluation of the curriculum.

In addition, the knowledge we gain from your experiences will add to the knowledge base in mathematics education, especially with regard to how teachers can learn a new content area and pass this knowledge on to their students.

Confidentiality

The information and data derived from the surveys, assessments, journals, videotapes and observations will be kept strictly confidential. It will be stored securely in a locked file and will be made available to the research team to use for research, presentation, and publication purposes only. No reference will be made to your name either in oral or written reports and transcripts that could link you individually to the study. To keep your identity confidential, all teachers will be identified by a random number. We will use a master list with codes which will replace names to the study data we collect. This master list will be kept in a locked file cabinet at the Friday Institute. The audio or videotapes will be digitally recorded and stored on a secure server at the Friday Institute. The files will be destroyed five years after the completion of the study, with the exception of any data used in publications.

Compensation

You will receive no payment for your participation in this research study, and there are no foreseeable costs for you associated with your participation.

What if you have questions about this study?

If you have any questions at any time, you may contact Dr. Karen A. Keene at 919-513-3374. Her address is 502J Poe Hall, NC State University. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919-515-4514), or Carol Mickelson, IRB Coordinator, Box 7514 NCSU Campus (919-515-7515).

Participation

Your participation in this study is voluntary; you may decline to participate without penalty. Your participation is not part of your job requirement. If you decide to participate, you may withdraw from the study at any time without penalty. If you withdraw from the study before data collection is complete your data will be returned to you or destroyed at your request.

Please initial by the statements that apply to you.

_____ I have read and understood the above information.

_____ I will allow personnel from the MINDSET project team to visit my classroom and collect data about my planning and instruction.

_____ I give permission to the MINDSET project team and North Carolina State University to make audio-video recordings of me while teaching in my classroom. I understand that the video recording will be used as a record of the lesson and the discussion taking place and may be used for publication and presentation purposes.

_____ I consent that a transcript of the audio-video recording of the classroom observation can be made.

_____ I will allow personnel from the MINDSET project team to interview me.

_____ I give permission to the MINDSET project team and North Carolina State University to make audio-video recordings of me during the interview. I understand that the video recording will be used as a record of the interview and the discussion taking place and may be used for publication and presentation purposes.

_____ I further consent that a transcript of the audio-video recording of the interview can be made.

_____ I will allow personnel from the MINDSET project team to send me surveys, feedback forms, and other forms used to describe my teaching experiences that I will complete to the best of my ability.

_____ I will allow personnel from the MINDSET project team to send me attitude surveys and assessments, which I will give to my students. I understand that these surveys and assessments will not count towards my students' grades or standings in my class.

Please complete and sign.

By signing below, I am giving the project team and NC State permission to use those items initialed above for record keeping purposes, for promotional purposes on the website, and for research purposes.

____

Full Name

____

Signature

Date

Address

City, State, Zip

Email

APPENDIX E

Interview Protocol Form- Student

PART I:

Q1: Can you describe your experiences in mathematics? Which classes did you take? What did you like/dislike in those classes?

Q2: Do you like mathematics? Why/ Why not? How confident are you about solving mathematical problems?

Q3: Have you ever used any kind of technology in your mathematics classes? (If yes) Which kind of technologies did you use? What did you do using those technologies? Did these uses of technology help you learn better?

Q4: What did you like/dislike about using technology to learn mathematics? How confident are you about using technology?

PART II:

Q5: Please talk about your experience with Voice Thread in this class. Did you find using Voice Thread beneficial to practice problems? Why/ Why not?

Q 6: Please talk about your group work using Google Documents? How did you communicate and collaborate through Google Documents with your peers and teacher?

Q7: How do you think your interaction/communication with your teacher and peers through Voice Thread affected your learning?

Q8: Did your communication and collaboration with your group members through Google Documents help you to learn content better? Why/ Why not?

Q9: Did you find using Voice Thread/ Google Documents was beneficial to accomplish your practice, homework, and project work for this course? Why or why not?

Q10: Did you like using Voice Thread/ Google Documents for this class? What did you like/ dislike?

Q11: Did using Voice Thread and Google Documents make any change on your mathematics and technology confidence, and your beliefs and feelings about mathematics?

Q12: How confident are you about your learning of the content of this class and about mathematics in general?

Q13: Do you think this class has changed your mathematics and technology confidence, and your beliefs and feelings about mathematics?

Expanded Interview:

Q13: Why do you think you did not sign in to the Google Document until the last night before the due date?

Q14: Why do you think you preferred to chat instead of writing on the actual document?

APPENDIX F

Interview Protocol Form- Teacher

Demographics- Interview 1

How many years have you been teaching prior to this year?

Have you ever used any kind of technology in your classes? (If yes) Which kind of technologies did you use? What did you do using those technologies? Do you think these uses of technology helped your students learn better?

How did you decide to teach Mindset curriculum to your students? How do you feel about teaching this curriculum? Do you enjoy it? Why?

Which kind of techniques, materials, and instructional methods do you use to teach this curriculum?

Can you talk about your experiences while you were teaching Mindset curriculum before?

What possible impacts do you foresee on students when they use Voice Thread and Google Documents while learning Mindset?

Interview 2

Can you talk about using Voice Thread and Google Documents to teach this class? Did these online tools help students to interact, communicate, and collaborate with you and with each other? Why/ Why not?

Which kinds of impacts did you observe on students' learning when they use Voice Thread and Google Documents to interact, communicate, and collaborate?

Did you observe any difference in their engagement when your students use online tools?

APPENDIX G

Teacher reflection probes

RP1: How do you think student work with online tools influenced their communication, collaboration, and interaction? (For Online-Tools classes)

RP2: Can you explain how the chapter played out? Do you feel that your goals of this chapter were reached? Why or why not? What do you think the students gained from this chapter? How do you know? (For both Online-Tools and No-Tool classes)

RP 3: Did student interaction, communication, and collaboration through online tools help to learn the content of this chapter? Why/ Why not? (For Online-Tools classes)

RP 4: Do you think the students obtained a deep understanding of the content? Why or why not? (For both Online-Tools and No-Tool classes)

RP 5: Can you describe student attitudes when they used online tools? (For Online-Tools classes)

RP 6: How would you describe student engagement during this chapter? (For both Online-Tools and No-Tool classes)

APPENDIX H

Mathematics and Technology Attitude Scale

	Hardly ever	Occasion ally	About Half the time	Usually	Nearly Always
I concentrate hard in mathematics [BE].	HE	Oc	Ha	U	NA
I try to answer the questions the teacher asks [BE].	HE	Oc	Ha	U	NA
If I make mistakes, I work until I have corrected them [BE].	HE	Oc	Ha	U	NA
If I can’t do a problem, I keep trying different ideas [BE].	HE	Oc	Ha	U	NA
	Strongly disagreed	Disagree	Not sure	Agree	Strongly Agree
I am good at using computers [TC].	SD	D	NS	A	SA
I am good at using things like VCRs, DVDs, MP3s and mobile phones [TC].	SD	D	NS	A	SA
I can fix a lot of computer problems [TC].	SD	D	NS	A	SA
I can master any computer program needed for school [TC].	SD	D	NS	A	SA
I have a mathematical mind [MC].	SD	D	NS	A	SA
I can get good results in mathematics [MC].	SD	D	NS	A	SA
I know I can handle difficulties in mathematics [MC].	SD	D	NS	A	SA
I am confident with mathematics [MC].	SD	D	NS	A	SA
I am interested in to learn new things in mathematics [AE].	SD	D	NS	A	SA

In mathematics you get rewards for your effort [AE].	SD	D	NS	A	SA
Learning mathematics is enjoyable [AE].	SD	D	NS	A	SA
I get a sense of satisfaction when I solve mathematics problems [AE].	SD	D	NS	A	SA
I like using technology for mathematics [MT].	SD	D	NS	A	SA
Using technology in mathematics is worth the extra effort [MT].	SD	D	NS	A	SA
Mathematics is more interesting when using technology [MT].	SD	D	NS	A	SA
Technology that I have used in mathematics classes helps me learn mathematics better [MT].	SD	D	NS	A	SA