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An Exploration of Student Attitudes towards Online Communication and Collaboration in Mathematics and Technology

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ABSTRACT

The idea of using online tools in face-to-face mathematics instruction aims to enhance student attitudes by providing more challenging problem-solving and knowledge-building platforms with more time and space flexibility. This study, which is a part of a large comprehensive study, was completed with four high school classes of two teachers. The data was collected through student and teacher interviews, teacher reflections, and the Mathematics and Technology Attitude Survey (Pierce, Stacey, and Barkatsas, 2007). Each teacher had two classes. One of each teacher's classes was assigned as the Online- Tools class that was introduced and had access to online communication and collaboration tools; and the other class was assigned as the No-Tools class that was not introduced any online technologies. Statistical analysis of the attitude survey revealed significant differences between Online-Tools and No-Tools classes for the 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 from pre- and post-survey; even if the difference between the overall mean values for the Online-Tools and No-Tool classes was not statistically significant. Based on the student interviews, the majority of the students had positive attitudes towards the online tools, Voice Thread and the Google Documents, and using them in their mathematics class; and they had increased appreciation to mathematics as a field.

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Keywords:
Mathematics Education, Student Attitudes, Blended Learning, Online Tools..

Introduction

New developments in learning sciences require society to provide more challenging problem-solving and knowledge-building platforms to students with more time and space flexibility (Resta & Laferrière, 2007). In its 17th ICMI study (2010), the International Commission on Mathematical Instruction (ICMI) discussed several topics concerning technology uses in mathematics instruction. In the section named Connectivity and Virtual Networks, Celia Hoyles and Lagrange (2010) emphasized the potential of the virtual technologies and urged about the expected impact of connectivity on mathematics teaching and learning:

> 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… there would be considerable impact on teaching and learning in the short, medium, and long term (p. 439).

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Computer-supported collaborative learning (CSCL) is an emerging field of research dealing with how computers can be used to support student learning through communication and collaboration. Gress, Fior, Hadwin, and Winne (2010) point out the need for evidence-based research in CSCL that provides in depth descriptions of the participants, contextual elements, and analysis methods. Through the analyses of student attitudes using online tools for communication and collaboration, this study aims to contribute to the understanding and development of CSCL research in mathematics education at the high school level. At the same time Dillenbourg, Järvelä, and Fischer (2009) argue that the affective and motivational aspects of computer-supported collaboration, one of the dimensions of attitude, have been neglected in past studies. The attitude analysis in this study is expected to contribute to CSCL literature in terms of outcome variables, and also provide information about affect issues in CSCL.

The use of online tools in this study is in blended form, which is defined as the mode of instruction that combines face-to-face and virtual methods and tools (Bonk & Graham, 2012; Pape, 2010). So and Bonk (2010) suggested that a lot of CSCL contexts are in blended mode of instruction, rather than being completely online or face-to-face. Blended learning extends the school day or year while developing the 21st-century skills for students, while it continues to offer the critical discourse features of face-to-face instruction (Pape, 2010; So, 2009). However, according to the reviewed literature, most of the research on blended mode has been at the university level or about online courses (Bonk & Graham, 2012; Graham, C. R., & Dziuban, C., 2007; Picciano, Dziuban, Graham, 2014). This study explored blended learning in the high school mathematics.

Additionally, Wilson (2008) points out the low societal levels of mathematical competence and confidence; and importance of promoting positive student attitudes to learning mathematics. Recognizing the rapid change in technology and the need to provide students with platforms in which they can experience current communication and collaboration technologies, we strongly believe that using online communication and collaboration technologies in their high school mathematics experience can help students to learn mathematics better and to improve their attitudes towards mathematics and learning technologies as well.

Defining Attitude

Attitude is defined as individuals' inclination and disposition toward a person, place, idea, or any other concept by Reed, Drijvers, and Kirschner (2010); but the reviewed literature indicates that there are many ways to define and investigate attitude as a concept (Bain, 1928). In the 1930s, when the first studies were conducted on attitude, researchers examined attitude as a single dimension regarding feelings or beliefs (Breckler & Wiggins, 1989); while 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). Breckler (1984) reports that the distinction of affect, behavior, cognition and the roots of the triad system of feeling, acting, and knowing are really old. The concept of attitude formally started to be explained with this tripartite model in late 1940s. According to Breckler (1984) three components of attitude distinguishable in terms of their formation, not all components built up on cognitive processes. Affect (or emotion) can be a result of classical conditioning by pairing up an object with an affective stimulus, while behaviors also can be developed through non-verbal or non-cognitive mechanisms.

Hannula (2002) identifies the emotion and cognition concepts as the central components of attitude. Psychology research also determined these two concepts as the main components of the attitude formation (Crano & Prislin, 2008). Some early theorists (e.g., Fishbein & Ajzen, 1975) emphasize the cognitive processes in attitude development; however, later on more evidence-based research indicated the significant impact of affective processes on attitude development (as cited in Crano & Prislin, 2008). According to Crano & Prislin (2008) affective and cognitive processes pertain to different phases in the formation and change of attitude. According to Hannula (2002), the quality of the teaching and the social-psychological climate of the class are two contributors of student attitudes toward mathematics. Analyzing mathematics and technology in class and student attitudes toward these concepts requires analyzing various components 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 determined as the contributors in this

context by Reed et al. (2010). Galbraith and Haines (1998) suggested student attitudes toward mathematics and towards the particular technologies used are the main concepts that should be investigated to understand the impact of computers and other technologies on mathematics teaching and learning. The attitude survey and qualitative instruments in this study measures common essential concepts of attitude suggested by the reviewed studies such as mathematics and technology confidence, student engagement, and attitude to particular technologies that were used in this study.

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

There is limited number of studies that directly address the effects of technology use on student attitudes (Li and Ma, 2010). For example, Ozel, Yetkiner, and Capraro (2008) examined the use of different technologies in mathematics in the K-12 level; like calculators, immediate response devices, computers, and Web-based applications. The authors report improvement in student attitudes toward learning, higher achievement and conceptual understanding, and improved engagement with mathematics among the positive effects of technology integration. They listed some essentials to integrate the technology effectively such as equitable student and teacher access to technology, adequate teacher training in the use and implementation of technology within their curricula, and timely teacher access to technical support. A collaborative study between a secondary school teacher and a university professor also reported improvement in two types of student attitudes; first type is referring to valuing and appreciating the discipline focusing on the affective side of the attitude rather than cognitive and second type refers to the general mathematical abilities such as critical thinking, mental openness, objectivity, creativity, and so on as a result of using technology in mathematics classes (Garcia & Romero, 2009). In both studies, the technologies included both online and other technologies, and they were not used specifically for communication and collaboration purposes. However, this study particularly focuses on the use of online technologies and especially for communication and collaboration purposes. We sought to examine two types of attitude development addressing the two research questions below:

a) In what ways are students' attitudes affected by using online communication and collaboration tools with an authentic mathematics curriculum at the high school level?
b) Do student attitudes differ between students using online communication and collaboration tools and students using no tools?

Material and Methods

The Curriculum and the Tools

The curriculum that has been employed in this study is an innovative fourth-year high school mathematics curriculum that consists of contextual problems from business as well as from students' lives. All the contexts involve decision-making in the students' world or the world of industry and government, and is generically named Mathematics for Decision Making (MDM) (MINDSET Project, 2014). This new course uses deterministic (algebraic) and probabilistic modeling. It is an authentic curriculum and includes real world tasks. Students are required to take the basic algebra and geometry classes to take this course, so they had a similar background and have enough mathematical skills to solve the problems in this curriculum. For example, students were given problems such as making the decision of choosing the right college to attend, choosing a cell phone plan, or choosing a car and they are required to use the multiple criteria decision-making tools that they have learned during the in-class lectures for their solution.

The 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)). The MINDSET curriculum was chosen for this study because of its unique structure. Within this curriculum, 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. For example, first problem of the first chapter is about a student who has been accepted by four different colleges. He is searching for the right college to attend and he uses decision-making tools that are explained in detail in the solution part of the problem to make the decision. First online tool, Voice Thread, was used as a supportive tool to practice those first problems providing an enriched and enhanced learning environment for reinforcement. Voice Thread is multimedia software through which images, videos, and documents can be shared with users in an online

platform and it allows user comments on the slides. Problems along with its solution were presented in the Voice Thread and students were asked to answer some questions through the presentation by leaving comments. The Voice Thread 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.

Further problems in MINDSET chapters require students to work in groups, to have discussions based on the model they have learned in the first part of the chapter. For example, for the first chapter as their final project, students worked in groups of three and asked to choose a topic that they can use the technique they learned in the college problem. The second tool, Google Document, was used for those problems like a structured Wiki as a platform for collaborative student work to solve those problems; and for synchronous and asynchronous student-student communication. 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 Document is an open source that enables collective generation of knowledge by supporting synchronous editing, comment writing, and saving versions of the document (Educause Learning Initiative, 2008). 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). According to Blau and Caspi (2009), similar to Wikis, Google Documents enables collaboration by editing a document written by other students, as well as allows modifications through comment writing without editing the document itself.

Methods

This study is a multiple-case study with quantitative and qualitative data. Two high school teachers and 79 students in four different classes at a public high school in South East of the United States participated in this study, each teacher had two classes. The participants were 42 female and 37 male students. The course that was chosen for this study assumes that students completed a second-year algebra course and thus met the new "fourth year above Algebra II" mathematics requirement in the state. 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. 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.

One of each teacher's classes was assigned as the Online-Tools class that was introduced and had access to online communication and collaboration tools, and the other class was assigned as the No-Tools class that was not introduced any online technologies. Teacher A and her two classes has been identified as the Case 1 and Teacher B and her two classes has been identified as the Case 2, as given in Figure 1, for the purposes of this study. Online- Tools classes named as TA (technology & teacher A) and TB (technology & teacher B), and No-Tool classes named as CA (control & teacher A) and CB (control & teacher B). In this sense, students were identified by their classes and random numbers. For example Student TA1 is a student from Teacher A's Online-Tools class.

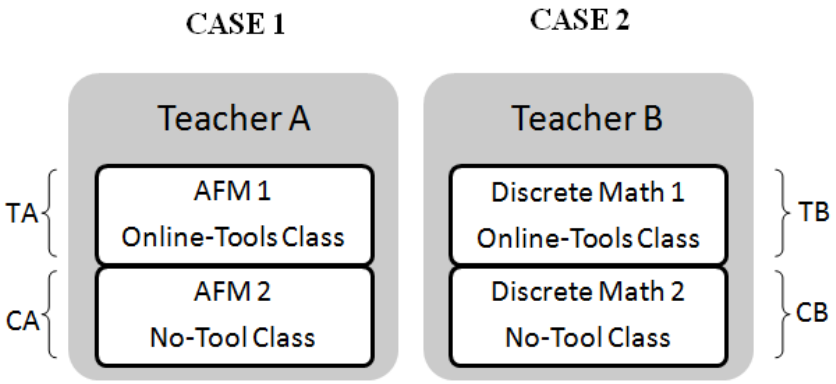


Figure 1. Definitions of case 1 and case 2.

Instruments

Attitude survey. 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 (p. 293). The scale was tested with 350 students. The statistical analysis from the testing data indicates "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).

Interview protocol forms- student (see Appendix A for sample interview questions). One semi-structured interview with two parts was conducted with each student who participated in this study (N= 69). *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, student feelings and beliefs about the tools that they used during this study, their opinions about the effects of using the online tools on their learning, feelings, and beliefs about mathematics and technology. Each student in the Online-Tools classes was asked all twelve questions in Part I and Part II; while students in comparison groups were asked all the questions in PART I of the interview protocol and one question from the PART II of the interview protocol. 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 duration of the interviews was around 20 minutes. During the interviews, voice recorder was used with written permission of the participant.

Interview protocol forms- teacher (see Appendix B for sample interview questions). 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 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 opinions about 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. The duration of the interviews was around 30 minutes. During the interviews, voice recorder was used with written permission of the participant.

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. The same reflection probes form was completed by teachers for each chapter. Reflection probes were related to teacher opinions about student learning and attitudes during each specific chapter (see "data collection procedures" section for details about which chapters were used for each case).

Data Collection Procedures

This study was conducted for seven chapters of a course. The course was 15 weeks, started at the end of January and finished in May (short break in March). The study was limited to some chapters based on teachers' suggestions, since those chapters require more student communication, collaboration, and group discussions. Case 1 included chapters 1, 2, 3 and 11; and Case 2 included chapters 9, 10, and 19. Students in all four classes completed the attitude pre-survey on the first day of the study. Then they were assigned the first Voice Thread and the first Google Document assignments in the first week. No-Tools classes always had the same homework and projects with the Online-Tools classes; they were just not introduced any online technologies. The student comments on Voice Thread and student work in Google Documents were saved automatically by the tools themselves. Google Document has a feature of recording different revisions of a document which includes the time the document was revised and the e-mail of the person who revised the document. During the data collection and analysis processes, the researcher examined these Voice Thread comments 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 during the study. The first teacher interviews were completed with the teachers in the first week of the field work. Then, the second interviews were completed at the end of the field work. They completed a reflection after the instruction of each chapter. Students completed the attitude post-survey on the last day of the study.

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 section, the quantitative methods that were used to analyze the attitude survey are examined first, and then the methods that were used to analyze the qualitative data are explained.

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. The size of the sample was 75. The survey responses analyzed with block design in SAS (Randomized Complete Block Design, REML, with two blocks) to test: Is the (Post Mean –Pre Mean) score significantly different from zero? 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 type 3 and the REML approach, which is a particular form of maximum likelihood estimation. There was no statistically 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 using REML, Kenward Rogers Approximation is a method for estimating the error degrees of freedom. KR approximation gives a much larger degrees of freedom for error here, due to the fact that the teacher (block) and the teacher*class (block*treatment) were estimated at zero).

Qualitative analysis. Some strategies were used for early organization of the qualitative data during the data collection include: Writing a daily memo and keeping reflective field logs to capture the researcher's thoughts when they occur; developing analytic files for each piece of data collected, like quotation files; and developing rudimentary coding schemes by writing down the main points from the data into logs (Glesne, 1999). Then we started code mining to determine the themes and patterns. One of the authors did the primary coding, and two of the authors provided feedback on coding. The coding started with the student interviews which was done in an excel spreadsheet. Not all of the interviews were transcribed; instead the researcher listened to the interview recordings. At the beginning of the coding, the researcher, who did the primary coding, was trying to identify any possible segment of data that might be related to the questions. The researcher listened to the first interview and recorded every part of the interview that seemed related to the study under a category, which was defined as open coding by Merriam (2009). 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 and reflections. Sometimes the researcher decided to make a category, a subcategory, merged categories, or subcategories with one another. These sorting of both categories and data continued through the coding of all pieces of data.

Findings

The data for this multiple case study was collected through student and teacher interviews, teacher reflections, and an attitude survey administered to students. The results for the analysis of the survey and student interviews are given below organized by two research questions. Teacher comments are given at the end of the findings section, since they intertwined and overlap in terms of answering two research questions.

Effects of Online Communication and Collaboration Tools Students' Attitudes

Quantitative findings. Table 1 presents the mean values for the subscales of the pre- and post-survey. As seen in the table, there were both positive and negative changes in terms of the minimum, the maximum, the median, the upper and the lower quartiles for all of the subscales. So, not a big change was seen on the mean value or the change in the standard deviation over shades the positive or the negative change in the mean value.

Table 1. Means and standard deviations of MTAS subscales for pre- and post-survey

CASE 1 (N=19, TA)				**CASE 2 (N=15, TB)**			
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 second research question later in the study. Below student opinions related to the effects of using online tools on their attitude to technology and mathematics are presented based on the student interviews.

Comments from the Online-Tools classes. To support the survey data interviews were conducted with students. Students were asked about their opinions in terms effects of using online technologies on their attitudes towards mathematics and technology during the interviews. Two of the questions were: Did you like using Voice Thread/ Google Document for this class? What did you like/ dislike? Table 2 presents the major themes from the student comments about their positive or negative attitudes to Voice Thread and Google Documents and using them in their mathematics class. In total, 41 students were interviewed from the Online-Tools classes. 37 of those participants had either positive or negative opinions, while four of them

were neutral. The percentages were calculated out of those 37 students. For example, 19% of 37 students had positive comment about the communication feature of the online tools. Some exemplar student comments have been provided below.

Table 2. Emerged major themes about student attitude

Factors affecting attitude towards online tools	Reasons (N = 37) (in total 27 positive comments and 19 negative comments, some students had both positive and negative comments)	% of Students in total pos. or neg. comments
Communication	Direct communication with teacher **(positive)**	
	Easy and neat communication and collaboration **(pos.)**	19
	Not enough or too much participation by peer **(negative)**	16
	Preference of face-to-face communication **(neg.)**	
Effects on learning	Making some tasks easier/ enjoyable **(pos.)**	19
	Presentation in small pieces/ less reading **(pos.)**	
	Slowing down some tasks **(neg.)**	14
	Preference of hands-on activities **(neg.)**	
Time	Time efficient **(pos.)**	
	Time flexibility to do turn in the homework **(pos.)**	11
Technical factors	Technology savvy **(pos.)**	19
	Technical problems **(neg.)**	
	Audio annoying / repetitive **(neg.)**	14
	Requiring the internet access **(neg.)**	
Other factors	Accessibility **(positive)**	5
	It is a new concept **(negative)**	8

Communication. During this study, students had face-to-face instruction with their teacher every school day. Even if they had an opportunity to communicate with their teacher face-to-face some students reported how they felt more comfortable to communicate with their teacher through the online tools. For example, Student TA6 says:

> *"I like that (Voice Thread) 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 Voice Thread), you are not in the class asking them. You are kind of asking the teacher directly, so I do like that part of that."*

Many students reported using Google Document for communication and collaboration for their group work is neater, easier, and cooler. For example, Student TB21says: "I liked the easier way to communicate, neater, more professional, and easy to save." There were also students who had more critical comments about using online tools to communicate. They mentioned that it was hard to communicate through the Google Documents, since they had to type everything and sometimes they could not understand each other's' opinion well enough by typing and it slows down the communication process. For example Student TA14 says: "It was easier to communicate face-to-face. You were able to get everything out right away instead of typing in everything." Also, some students talked about they could not benefit from the online communication and collaboration, since their partner(s) did not participate mush in the discussion of the problem and did not have adequate contribution in the solution process.

Effect on learning. Some students talked about how Voice Thread helped them to find the specific information they need when they practice and the presentation was in small pieces with less reading. Student TB17 said: "I liked that it (Voice Thread) ordered stuff. If you needed to see something, you can go back see whatever slide." Student TA21 was talking about his experience in class saying that: "When I first heard about AFM (the current class) 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 Voice Thread than book problems." Some students, in more critical comments, mentioned typing as a disadvantage. 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."

Time and technical factors. Students reported time flexibility as an advantage of doing homework via online tools, and some students also mentioned that it was time efficient. A small number of students reported that they had technical problems when they were doing their homework using online tools. 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". Even if, a couple of students reported some technical problems using the online tools, "being technology-savvy" was the most reported reason by students for their positive attitude in class. Student TA8 explained that he liked being able to interact with teacher outside the class using technology. Student TB14 pointed out some specific tasks that were easier using technology: "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."

Technology effects on mathematics and technology confidence. In addition to their feelings about the online technologies, students in Online-Tools classes (N = 41) were asked if using Voice Thread and Google Documents make any change on their mathematics and technology confidence. Figure 2 demonstrates the percentages for student confidence based on the student comments.

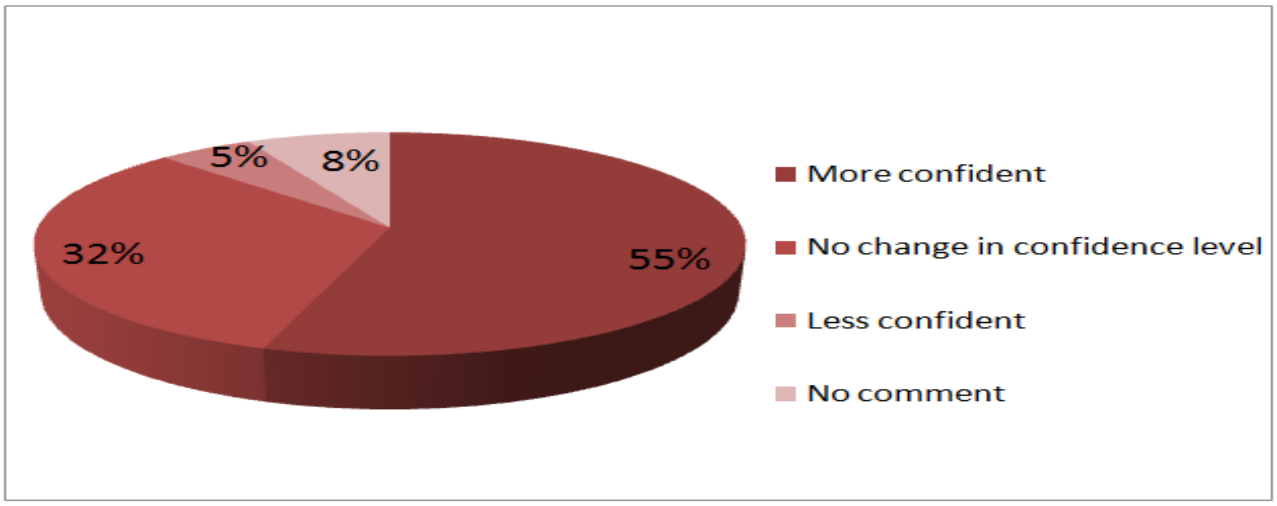


Figure 2. Change on students' confidence level with percentages after using online tools

As presented above, most of the students liked using more technology in their mathematics class and some students reported getting more technology- savvy instruction raised their confidence level. For example, when Student TA14 said: "I think so (using Voice Thread 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 said: "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." Students who said they feel no change on their mathematics and/or technology confidence mostly mentioned two reasons: the content of the class and the technology skills that they needed to use online tools were basic and easy; and they were already completely confident about mathematics and/or technology. Student TB6 added that using online tools made the class more exciting than other math classes. Student TA9 also mentioned that there was an improvement about how to learn mathematics even if she did not feel any more or less confident about mathematics and/or technology: "I have always been really good at technology. It was not a lot of deep math… Using the tools did not increase my math skills, but it has just increased the way I do things." Two students reported that after using online tools they felt less confident. Both of them mentioned that they do not feel comfortable while working with technology in general.

Attitudes Differences between Students Using Online Communication and Collaboration Tools and Students Using No Tools

Survey results. Seventy-five students completed the 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. Since the sample sizes would be so small when we only have Online-Tools classes, statistical tests were not conducted to see whether "Post-Pre" survey was significantly different from zero for just the Online-Tools classes; instead all classes combined, and analysis were done with block design. 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. The same analyses were done for whole scale first, and then for each subscale. Table 3 provides the information about the test results for the pre- and post-survey.

Table 3. 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. The numbers that appears under the Pr > |t| column are the p-values in SAS output.

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

In Table 3, since the p-values > 0.05, for α = 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], behavioral engagement [BE], and attitude to learning mathematics with technology [MT] subscales. On the other hand, there was a statistically 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). For the AE subscale the Online-Tools classes had a higher mean than the No-Tool 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.

Mathematics confidence and beliefs and feelings about mathematics. Students both in Online-Tools and No-Tools classes were asked about their confidence level in current class and in previous mathematics classes. As seen in Table 4. student answers were coded in five categories: completely confident (if student said feel "very confident" or gave "9 or 10" when asked to rank confidence level on a scale of 1-10, quite confident (if said "pretty confident" or they gave "7 or 8" on the scale, fairly confident (if said "fairly confident" or gave "5 or 6", not confident (if said "not confident" or gave less than 5, and no comment (if they did not? mention anything).

Table 4. Confidence levels for current and previous mathematics classes.

Confidence Level in current class	**% of Students**		**% of Students**	
	TA	***TB***	***CA***	***CB***
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**		**% of Students**	
	TA	***TB***	***TA***	***TB***
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

Students were also asked whether this class made any change on their beliefs and feelings about mathematics. Students mostly had highly 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. At the same time most students mentioned that the current class had a very different structure than other mathematics classes. Most of the students mentioned that they like the class structure. They also liked how it relates their mathematics knowledge with real life in a logical sense. 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 I would actually be good at discrete (current class). 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."*

Below some exemplar teacher comments from the teacher interviews and teachers reflections have been provided.

Teacher opinions

Confidence and engagement are given among the most important measures of attitude in the reviewed literature (Galbraith & Haines, 1998; Vale & Leder, 2004; Pierce et al., 2007). In this regard to investigate teachers' opinions about the students' attitude, they were asked about student engagement for their Online-Tools and No-Tools classes in the interviews and weekly reflections. Since it would be hard for teachers to observe students' confidence, the confidence component was not included in the interview questions and the reflection probes. The prominent quotes comprising answer to both questions are presented here. Teachers had different ideas about their students' engagement when they used online tools. In summary, Teacher A reported that both Voice Thread and Google Documents had a positive impact on student engagement; while Teacher B mentioned that she did not observe any effect of online tools on student engagement. When the interview question above was asked, 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 supposed to turn in a separate piece of paper."*

Additionally, in her reflection for Chapter1 she said: "Students were actively engaged in this chapter. I like the Voice Thread and many students said that they liked this tool". 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. As an answer to 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."

Discussion

This study was carried out with the purposes of investigating the ways that students' attitudes are affected by using online communication and collaboration tools; and examining the attitude differences between students using online communication and collaboration tools and students using no tools. It was found that the impact of online tools may differ in terms of the emotional, behavioral, and cognitive aspects of student attitude. Statistical analysis of the attitude survey revealed statistically significant differences between Online-Tools and No-Tool classes for affective engagement subscale on 95% confidence level. Even if there was not a statistically significant difference between Online-Tools and No-Tool classes over the whole scale; and for Mathematics confidence [MC], confidence with technology [TC], behavioral engagement [BE], attitude to learning mathematics with technology [MT] subscales; there was a positive change in the average score for the whole scale for the Online-Tools classes.

Although there have been limited number of studies about the effects of using online tools on student attitude (Li and Ma, 2010), especially in the field of mathematics (Spradlin, 2009); the reviewed studies report improvement in student attitude when students used online tools (Garcia & Romero, 2009; Nguyen, Yi-Chuan, & Allen, 2006; Ozel et al., 2008; Pierce et al., 2007). In those studies, some online technologies were used; but not necessarily for communication and collaboration purposes. Other technologies were also used in addition to online tools. The research methods were mostly quantitative. For example, Ozel, Yetkiner, and Capraro (2008) examined the use of different technologies in mathematics in the K-12 level and the authors reported improvement in student attitudes and improved engagement with mathematics among the positive effects of technology integration. Another collaborative study between a secondary school teacher and a university professor also reported improvement in student attitudes as a result of using technology in mathematics classes as well (Garcia & Romero, 2009). Other studies also indicated positive impacts on student achievement, attitudes, and other variables; when technology used (Spradlin, 2009). For this study the Google Documents was used for communication and collaboration purposes, Voice Thread was used as both a communication and practice tool. Both of those tools are completely online. Both quantitative and qualitative instruments have been used for this study. Quantitative analysis of student attitudes in Online-Tools and No-Tool classes demonstrated mixed results, while there was a slight positive effect on student attitudes for the Online-Tools classes according to qualitative data. 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. Students did not report any information about their behavioral engagement; but as teachers and students pointed out in several places in the interviews, use of online tools led to some positive behavioral changes for students. For example, students could communicate with their partners and ask questions easily when they were face-to-face as opposed to being in the same Google Document group. Being a part of the same group on an online platform encouraged and endorsed students' face-to-face interaction.

On the other hand, when students` responses to the interview questions related to their confidence level for mathematics in general and in current class were analyzed, an increase on students` confidence in current class both for Online-Tools and No-Tool classes was seen. These results imply that the structure of the class and the curriculum might also be one of the factors influencing the change in student attitude. The curriculum, Mathematics INstruction using Decision Science and Engineering Tools (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. These findings about student confidence based on the student interviews show consistency with a similar study that reported attitudinal improvements for students when they were provided more authentic learning experiences (Brewe, Kramer, & O'Brien, 2009).

From a theoretical perspective, the current study sheds light on the three big concepts given by Vygotsky (1978) in social constructivist theory; culture, language, and zone-of-proximal development. It is important to discuss Vygotsky`s theory when technology used in the classroom 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. Even if those three concepts were nested with each other a lot of times, shortly we can say using online tools bringing a new learning culture to the learning environment. The new understanding of time, technical factors, and some other factors in student comments mostly distinguishes this new culture from more traditional, or solely face-to-face and/or solely online learning environments. We also see a new understanding for the language. Vygotsky defines the role of language in two forms: social language, which is the communication with others; and inner speech, the self-talk of the learner. In this study students used both forms of languages constantly. They had to present their thinking in written form in the Voice Thread assignments, which required them to talk to themselves about their own understanding that refers to their inner speech. Students were also required to present their understanding to their peers for Google assignments that refer to the social language they needed to use. At the same time, they helped each other to identify the drawbacks in their learning and learned from each other through their communications, which defined as zone of proximal development by Vygotsky. Another important aspect of learning in a social environment is given as self-efficacy by Bandura (1977, 1997), which defines how confident one feels about one's own ability to perform a task or learn a concept. The changes in the average scores between the pre- and post-survey were not significant for the confidence subscales; but when we look at the interview data, more than 50% of the students reported that they felt more confident about mathematics and technology after taking the current class. We can tell that there is a positive trend towards an increase in students' mathematics and technology confidence based on the student reports, but it may take longer to observe a significant change of the outcomes in quantitative form. At the same time the number of participants might not be high enough to observe that kind of change in the quantitative results of this study.

On the other hand, there are an unavoidable number of students who reported either no change on their confidence level or decrease for a couple of students. This may tell us something about the culture aspect of the learning. Even if a technology-savvy environment is a more familiar and comfortable environment for most of the students, there are students who do not like using technology that much in general. This aspect may direct us to two types of discussions: First, for those students who do not like using technology, it will not help them a lot to improve their attitude and engagement to provide a technology-rich environment. So, teachers should use various types of assignments both hands-on and technology-savvy ones to address the needs and preferences of all students. Second, even if for some students using technology is not much fun; it is an inevitable part of their lives and will be an important part of their college life or workplaces. Thus, it is important to provide students the opportunities for those students at least to have adequate experience to work with those technologies confidently as a part of their high school experience.

Limitations and Suggestions for Practice

According to the results of this study, it can be concluded that student learning and attitude might increase with the effective use of online tools in mathematics classroom. For the effective use of technology, some suggestions could be provided as following.

It is important to give enough time to students and teachers in mathematics classrooms to start using technology for learning purposes until they feel comfortable with using them. For this study, one class period (about 50 min.) was set aside for student training before beginning the implementation of online tools for homework and projects. Sometimes Online-Tools classes spent less time focusing on the content than the comparison classes did. For teachers who plan to use these tools for their classes, it is very important to train

students until they are comfortable using the tools before using them for assignments. About half of the training session was spent on solving technical problems, so it is also important to get technical support during the implementation of technology. The school where this study was conducted had only one internet server available which was not supporting 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.

This study demonstrates that to integrate contemporary methods and tools into the mathematics classroom, teacher support and involvement are crucial. Teacher training is also necessary. It is always possible to experience something unexpected during an implementation, so it would be wise to have a *Plan B* that a teacher can directly move to. Students did not report any problems, while they were working outside of the school; but they had some problems because of the overload to the same server when they were working on group works. So, it is important for teachers to be prepared for those types of issues to avoid frustration by students.

Directions for Future Research

The following recommendations should be considered by researchers for the future studies:

- This study employed a blended model in the mathematics classroom. Designing future studies on use of online technologies might utilize similar approach to provide students advantages of both the online communication and collaboration, and face-to-face interaction.
- Since some students prefer immediate feedback on their work and immediate response to their questions, more synchronous use of online tools would increase the benefit that those types of students get from the opportunities provided by online technologies.
- 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.

Conclusions

The findings from this study revealed the improvement potential of student attitudes in high school mathematics classes by using online tools for communication and collaboration purposes. Even if the quantitative findings of this study had mixed results; qualitative findings demonstrated considerable improvement on students' beliefs, feelings, and confidence levels for the majority of students. The technology also provided unique opportunities for students to create and communicate their knowledge. Although this study was completed in a short period of time with some limitations, it is promising that a lot of students made positive comments about using online tools in their mathematics class. For the affective engagement aspect, there was a positive change on student attitudes according to both quantitative and qualitative data. Some students reported that they plan to use Google Documents for their other classes and in college. As a result, it can be concluded that it is really important to provide opportunities for high school students to use online communication and collaboration tools for learning mathematics early before they enter the college classroom.

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Appendix A

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?

Q6: Please talk about your group work using Google Documents? How did you communicate and collaborate through Google Documents with your peers and teacher?

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?

Appendix B

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?

Did you observe any difference in their engagement when your students use online tools?