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Towards a Model for Authentic Problem-solving in Computer-Supported Collaborative Learning

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Abstract: By integrating the use of online technologies into high school students' mathematics education, this research aimed to provide more learning opportunities for students by providing them enriched potential for communication and collaboration while solving mathematical problems. This evidence-based study in mathematics education investigates the student-student, student-teacher, and student-content interactions in blended mode. Two teachers and 35 students at a public high school located in the southeastern United States participated in this study. Qualitative research methods are applied in this study. Data was collected through student and teacher interviews and contributions on the online tools. Two models have guided the data collection, organization, and analyses for this study: Stahl (2006)'s *Model of Collaborative Knowledge-Building* and Anderson's (2008) *Theory of Online Learning*. By combining these two models, a new modified model has been suggested for understanding mathematics learning in blended form to analyze social knowledge building in high school mathematics education.

Key Words: Online tools, Communication, Collaboration, Mathematics Education.

Bilgisayar Destekli İşbirlikçi Öğrenmede Otantik Problem-çözmeye Yönelik Bir Model

Öz: Bu çalışmada çevrimiçi araçların, lise matematik eğitimine entegresiyle, problem çözerken aynı zamanda iletişim ve işbirliği olanaklarını artırma yoluyla öğrencilere daha fazla öğrenme fırsatı sunulması amaçlanmıştır. Harmanlanmış bir matematik eğitimi ortamında yapılan kanıta dayalı bu çalışmada öğrenci-öğrenci, öğrenci-öğretmen ve öğrenci-içerik ilişkileri incelenmektedir. Çalışmaya Ameriaka Birleşik Devletlerinin güneydoğu bölgesindeki bir lisede görev yapan iki öğretmen ve aynı lisede öğrenim gören 35 öğrenci katılmıştır. Çalışmada nitel araştırma yöntemleri kullanılmıştır. Veri toplama araçlarını öğretmen ve öğrenci görüşmeleri ve öğrencilerin çevrimiçi araçlardaki katılımları oluşturmaktadır. Çalışmanın veri toplama, düzenleme ve analiz aşamalarında iki modelden yararlanılmıştır: Stahl (2006)'ın *İşbirlikçi Bilgiyi İnşa Modeli (Model of Collaborative Knowledge-Building)* ve Anderson (2008)'in *Çevrimiçi Öğrenme Teorisi (Theory of Online Learning)*. Bu iki modelin sentezlenmesi ile harmanlanmış formda öğrencilerin matematik öğrenmelerini anlama ve lise matematşk eğitiminde bilginin sosyal inşasını analiz etmek üzere modifiye edilmiş bir model önerilmektedir.

Anahtar Kelimeler: Çevrimiçi araçlar, İletişim, İşbirliği, Matematik Eğitimi.

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We are living in a rapidly changing global world and the information technology is one of essential components of the global economy, education, health, and so forth (Jensen and Arnett, 2012). For the new generation who grow up surrounded by digital media; the Internet is the first place they communicate, understand, learn, find, and do many things (Tapscott, 2009). Additionally, new technologies offer new ways of social interactions that leads change in availability and feasibility of various communities of practices. This change requires additional research on the development, structure and other aspects of those new types of social environments. Warschauer (2011) argues that a transformation of education is needed with the accelerating availability of the digital media. 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.

Computer-supported collaborative learning (CSCL) is one of the more dynamic research approaches in the field of education 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; Gress, Fior, Hadwin, Winne; 2010; Lazakidou and Retalis, 2010). CSCL is dealing with how computers can be used to support student learning through communication and collaboration (Stahl, 2010). Although many educators believe that CSCL environments allow learners to learn more deeply and meaningfully through current pedagogical techniques and provide learners time flexibility; it does not guarantee the effective learning just providing students the possibility of using collaboration tools (Kirschner and Erkens, 2013; Roschelle, 2013). Roschelle (2013) recognizes the empirical accomplishments of CSCL in the past 20 years, and emphasize the need to explore how CSCL changing learning theories. He adds more investigation is needed on individual, small-group, and community components of learning as well as interrelations between those elements.

Parallel to the increase in technology, the interest in mathematics education community to use digital technologies to improve teaching and learning continues to increase (Bueno-Ravel & Gueudet, 2009), especially for communication and collaboration purposes (Graham, J., & Hodgson; Beatty & Geiger, 2010; Stahl, 2010). According to Stahl (2010) online collaboration environments might support the design of learning activities that promote mathematics learning in multiple ways.In our study, students used two online technologies to communicate and collaborate with their peers and teachers, and interacted with mathematics content using the tools. Kirschner and Erkens (2013) identify three big elements of CSCL environments as pedagogical, social, and technological elements. Our current study deals with the pedagogical and technological aspects of computer-supported collaboration in terms of small-group learning in mathematics education. Two models guided the data collection, organization, and analyses for this study: Stahl (2006)'s *Model of Collaborative Knowledge-Building* and Anderson's (2008) *Theory of Online Learning*. By combining these two models, we have developed a modified model for understanding mathematics learning in blended form to analyze social knowledge building in high school mathematics education.

Computer-Supported Collaborative Learning

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). The diverse history of CSCL research includes various learning tasks and concepts such as collaborative knowledge building (Scardamalia, Bereiter, & Lamon, 1994; Lipponen, 2000; Weinberger & Fischer, 2006; Beatty & Moss, 2006); student reasoning and levels of argumentation (Hoadley & Linn, 2000); group cognition (Stahl, 2006), self-regulation (Fisher et al., 2007; Strijbos & Weinberger, 2010); and so on in several content areas. However, Hoyles et al. (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. Roschelle (2013) express that there should a dimension in CSCL research that is investigating variation in domains.

The aim of this study is to contribute 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. Three major concepts from the CSCL literature are included in this section because of their essential role in the field and their importance for understanding this study: cooperation and collaboration; scripting in CSCL; and knowledge construction and group cognition.

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 researchers have suggested various meanings for the whole acronym, Lipponen (2002) defines the focus of CSCL 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 important to view 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, and both emphasize the commonalities of the two words as: 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 each other's assumptions and thought processes; and students develop social and team skills.

Scripting in CSCL. In the context of CSCL, 'scripting' does not have the same meaning that it has in programming; instead it means specifying roles such as typist, discussion leader, and secretary; or in identifying activities and activity sequences in CSCL studies. In this research, scripting is determined as facilitating argument construction, instead of distributing activities or roles as suggested by Weinberger, Stegmann, and Fischer (2010). According to Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, and Fischer (2009), scripts scaffold collaborative learning processes and support learners through the activity types and sequencing. Assessment has been identified as another integral part of CSCL scripts by Villasclaras-Fernández, Hernández-Leo, Asensio-Pérez, Dimitriadis (2009). Therefore, in our study, the instructions for the collaborative activities to facilitate argumentation and the teacher rubric to guide and engage students in specific activities have been given to students during the online activities.

Knowledge Construction and Group Cognition. Local and global networks make it possible for people who are separated spatially or temporally to share thoughts by employing ingenious ways of communication and collaboration (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)

Text-based interactions via online collaborations are a new form of interaction; it is not the same as online learning where one instructor communicates with the geographically distributed learners (Stahl, 2006). Instead, students socialize, exchange ideas; and more importantly develop some kind of knowledge artifact that requires high-level cognitive activities. According to Stahl, the group cognition developed by small group interactions exceeds what each group member could achieve individually (Stahl, 2006, p.2). Stahl (2005) argues that meaning-making by groups cannot be attributed to any individual group members, even if "the participation of the individuals in the group process is necessary as sources of contributed utterances and as interpreters of the shared meaning" (p.1). Roschelle (2013) claims that beside all the empirical progress of CSCL research, the early definition, "a coordinated mutual effort to build shared knowledge", keeps its importance that emphasizes, and today it is named as 'transactional knowledge where "students building on each other's contributions (p. 1).

Models

Stahl`s model (Figure 1) represents a number of important phases in collaborative knowledge-building (Stahl, 2006). Arrows represent transformative processes and rectangles represent the products of these processes in the diagram. Stahl suggests that this is a limited representation. Since knowledge building is *a complex and fluid development*, it is hard to put in into boxes and it is important to know that it does not always follows the same path. The relations among the elements can be more complex forms instead of the sequential order that is implied by the diagram representation. Stahl claims that this diagram can "provide a starting point for discussing a cognitive theory of computer support for knowledge-building". Stahl's model was used as the first model for this study. This study provided students with platforms to communicate and collaborate with each other outside of the class with the goal of enhancing the opportunities that they could learn from each other. Stahl`s model was applied to analyze student-student interactions during their knowledge-building process.

One of the purposes in choosing Stahl's model was to see: which steps of social knowledge building, suggested by Stahl, were being observed when students used online tools in addition to face-to-face classes- blended mode. The blended mode in this study is more a course-level blending, since it combined distinct face-to-face and computer mediated activities as a part of the course (Bonk and Graham, 2006). Solving a mathematical problem through an online platform required students to make social statements and to explain their solution process in written form. Stahl (2006) recognizes the importance of artifacts in mediated cognition and emphasizes the importance of language and interaction as crucial factors for collaborative knowledge building platforms. 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, facilitated making connections and conclusions about student interactions using online tools, Voice Thread and Google Document. While student statements and questions in Voice Threads reflected more personal understandings, and 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.

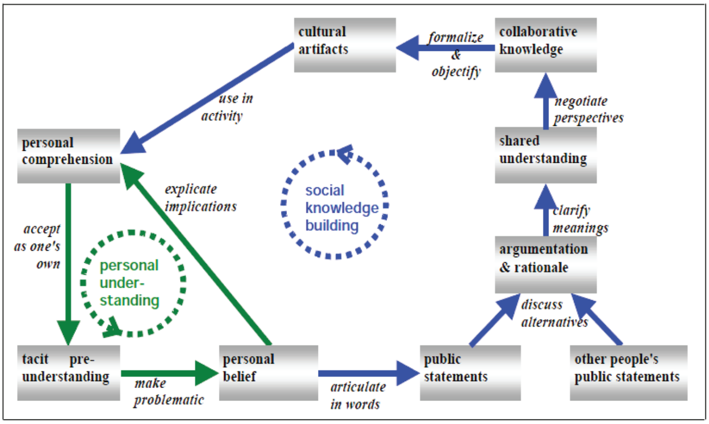


Figure 1. A diagram of knowledge-building processes. Adapted from "Group cognition: computer support for building collaborative knowledge," by G. Stahl, 2006, *Cambridge, MA: MIT Press*, p. 203. Copyright 2006 by Massachusetts Institute of Technology.

The secondary model of this study is Anderson (2008)'s model (see Figure 2). While Stahl envisioned components of social knowledge building and personal understanding processes that were developed among and between students during group work, Anderson provided a more global picture suggesting that additional influential interaction types are directly connected with student-student interaction that emerged with the support of online technologies. 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.

Anderson (2008) included student-student, student-content, student-teacher, teacher-content, teacher-teacher, content-content interactions as common components of an online learning model. Anderson`s model, in Figure 2, recognizes learners and teacher as being two major human actors in an online learning setting. The model illustrates their interactions with each other and with the content. Anderson suggests that net-based synchronous and asynchronous environments are rich and provide learners opportunities for learning of social skills and collaboration. Anderson`s model was employed to analyze student- teacher and student-content interactions for our current study, when students used online technologies, Voice Thread and Google Documents, to communicate and collaborate with their peers and teachers. Student-student interactions were not resolved using this model, since they were analyzed in detail applying Stahl`s model. The teacher-content, teacher-teacher, content-content interactions are not included in this study; since direct influences of those concepts on student-student interactions were not observed explicitly.

Research Questions

(RQ1) How do students` personal understanding and social knowledge-building develop when they used online technologies to solve mathematical problems?

(RQ 2) How do student-content and student-teacher interactions develop when they used online technologies to solve mathematical problems?

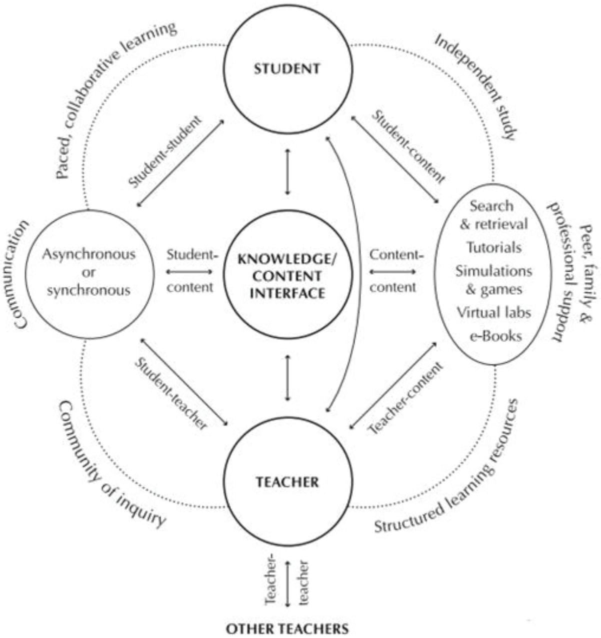


Figure 2. A model of online learning showing types of interaction. Adapted from "Towards a Theory of Online Learning," by T. Anderson, 2008, *In T. Anderson, T. (Eds.), Theory and Practice of Online Learning.* (pp. 45-75), Edmonton, AB, p. 61. Copyright 2008 by Athabasca University, AU Press.

METHODS AND MATERIALS

Participants

Two teachers and 35 students at a public high school located in the southeastern United States participated in this study. Both 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. Teachers had been using technology in their previous classes, but not necessarily online technologies. 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.

Student participants were juniors and seniors from the same high school. Students are required to take basic algebra and geometry classes before taking a MINDSET course, so they had adequate mathematical skills to conceptualize the MINDSET problems. At the beginning of the study, students completed a survey that included questions about their computer and Internet access at home; and their confidence in using technology. According to student responses, 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. All of the students in Teacher A`s class reported that they were very confident in using technology. In Teacher B`s class, 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.

The Curriculum and the Tools

The mathematics curriculum that was developed by the MINDSET[1] (**M**athematics **IN**struction using **D**ecision **S**cience and **E**ngineering **T**ools) research team was used in this study. The **MINDSET** curriculum uses math-based decision-making tools to present standard mathematics concepts in a non-calculus fourth-year mathematics course to enhance students' mathematical knowledge and skills, especially their ability to formulate and solve multi-step problems and interpret results. Some of the sample problem contexts are: choosing a college, buying a used car, minimizing water pollution, house renovations, locating emergency service centers in Tornado Alley, how to choose a cell phone plan, and waiting in line and customer service levels. 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.

Based on the structure of the MINDSET curriculum, two web-based tools were chosen for this research. The first one, Voice Thread, 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

[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)

Figure 3). The problem in Figure 3 is about choosing a college to attend for a high school student applying decision making tools from engineering. The Voice Thread environment provides a colorful way to present the content with support of pictures and audio to the text-based instructional materials. 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 (Stahl, 2008; Krebs & Ludwig, 2009; Krebs, Schmidt, Henninger, Ludwig, & Müller, 2010). 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.

Figure 3. An example of Voice Thread presentation and different forms of commenting on Voice Thread slides.

Settings

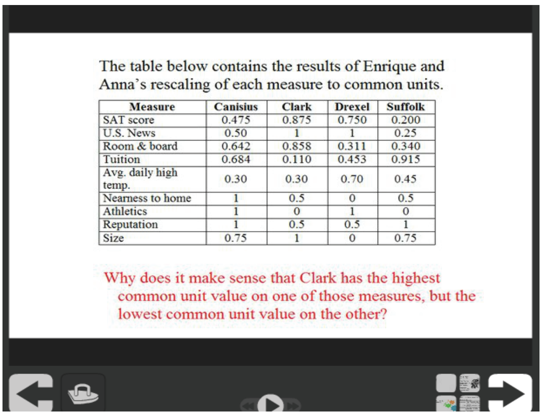
There were two computer laboratories in the high school in which this study was held. The first computer laboratory had thirty desktops with internet connection. The second computer lab had about sixty desktops computers and a working area. There were also forty laptops with the Internet connection available in the school for students by teacher reservation during the class period. 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.

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. Each teacher had their own classroom for regular instruction. 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. When students need more computers, computer labs or laptops on carts have been used.

Procedures

The research study was conducted over six months from the beginning of the spring semester through the end of the semester. Before the implementation, student training was completed for Online- Tools classes. During the training sessions, basic features of the Voice Thread and the Google Documents have been demonstrated; and students created their accounts and watched a part of the first problem presented in Voice Thread.

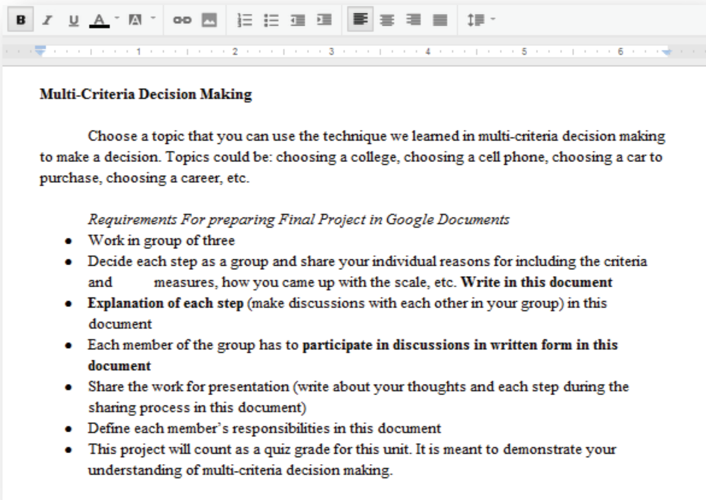
For each Online-Tools class, in-class problems for two chapters were presented in the Voice Threads. After the face-to-face instruction of each problem, students were given homework. For Online-Tools classes the homework was to practice the problem through the Voice Thread and answer the questions in red by leaving a comment (see Figure 4).



Measure	Canisius	Clark	Drexel	Suffolk
SAT score	0.475	0.875	0.750	0.200
U.S. News	0.50	1	1	0.25
Room & board	0.642	0.858	0.311	0.340
Tuition	0.684	0.110	0.453	0.915
Avg. daily high temp.	0.30	0.30	0.70	0.45
Nearness to home	1	0.5	0	0.5
Athletics	1	0	1	0
Reputation	1	0.5	0.5	1
Size	0.75	1	0	0.75

Figure 4. Homework questions asked in red in the Voice Thread presentation.

For the rest of the chapters, there was no Voice Thread to practice problems, but students in the Online-Tools classes completed homework problems in Google Documents as groups. Google Documents were used for homework problems and the final projects. Students worked in groups of two for homework problems, and groups of three for projects. Google Documents were used as a structured Wiki in which the problem, instructions, and the teacher rubric were presented for each homework problem or project. We have prepared a separate Google Document for each group in Online-Tools classes for each Google Document assignment. Then the students communicated and collaborated through the Google Document that was shared with only their group members to solve the problem (see Figure 5). For the Google assignments students were given limited in-class time to get familiar with the tools, and then they have worked on the problem solution through the Google Document outside of the 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, and either submitted the solution to the teacher or made a presentation in class. 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.



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 5. A Sample Google Document Assignment.

Data Collection

Interviews with students and teachers, class observations, and the content of online tools are sources of data for this study. Each data source will be explained in detail below:

Student Interviews. Semi-structured student interviews were among the primary data sources of this study. A single –piece interview protocol was prepared including two parts: PART I, baseline information of students; as prior experiences with mathematics, with technology, learning mathematics with technology; PART II, student experience of using online tools in the mathematics class with their own words to examine student perception about the interaction, communication, and collaboration using online tools. After a Google Document assignment, different participation levels among groups were observed. In response to this, expended interviews with students from different groups were carried out to hear about their communication and collaboration experience during the particular assignments. 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.

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. Teacher interviews were used for triangulation of the data collected through the student interviews and the other data. 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.

Google Documents. Student participation in the Google Documents was recorded through the revision history of the document itself. Those records informed the research question by monitoring individual student participation and contribution to the assignment. The records of student participation were also used for a triangulation component with student self-report from the interviews. The revision history of the Google Documents also led us 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.

VoiceThread Comments. Student comments on the Voice Thread 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. Similar to records of student participation in Google Documents, the records of student participation in Voice Threads were also used for a triangulation component with student self-report.

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 us to take notes of the emerging themes about any of the variables.

Data 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. The concepts in the first and second models, Stahl (2006) and Anderson (2008)'s models, were utilized as the categories to display the findings. Before organizing the data under the categories suggested by the models, we developed a coding and displaying process for the analysis.

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 category construction, sorting categories and data, and naming the categories (Merriam, 2009) steps were simultaneously followed to analyze the data.

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 into the same single spreadsheet and organized to determine the *recurring regularities* or *patterns* for the study; which were named as *categories* or *themes* by Merriam, 2009. We 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 it has been written 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. All interviews have been completed by the same pathway. For each interview, we 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 the observation notes to catch any other possible findings to answer the research questions. The names of the categories in the coding came from the models and our own words, or phrase that was used directly by participants.

FINDINGS

In this section, the findings about student-student, student-teacher, and student-content interactions are presented. Even if it is one of the components of Anderson`s model, the student-student interactions are presented in accordance with Stahl`s model; since this model provided a more detailed framework for student-student interactions. Student-teacher and student-content interactions are presented in accordance with Anderson`s model.

Student-student Interactions situated in Stahl's model.

Stahl (2006) offers *personal understanding* and *social knowledge building* as the two essential concepts needed as part of the knowledge-building processes for computer-supported collaboration to occur. Stahl also reports that these two concepts have a mutual constitution. Each component in Stahl's model is used as a category to analyze our research data. Under each category the findings and interpretations as revealed by the data are explained in relation to that specific component of the model. 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 applying Anderson (2008)'s model.

Personal understanding.

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). Individual understanding is one of the two units of analysis in Stahl's model as well. 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.

Stahl (2006) argues that even if the starting point of our learning is our tacit pre-understanding, there could be problematic parts in individuals` understanding. We may improve our understanding and reach new levels of comprehension through further interaction with the world. Student TB5 indicated a valuable feature of the Voice Thread as being a vehicle with which to move from tacit pre-understanding to a new comprehension by clarifying concepts: 'I used it (Voice Thread) 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 Voice Thread for that.' Student TA25 stated how Voice Thread helped him to bridge the gaps in his learning: 'I like stuff like that (Voice Thread) 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 (Voice Thread).' He had the pre- understanding of the content from the face-to-face class and visited the Voice Thread to settle that understanding in his mind and move to a new comprehension.

Student TA3, an Online-Tool Class student, mentioned that he used Voice Thread as a practice tool for his personal comprehension. When asked how Voice Thread helped him to learn better, he said: '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 Voice Thread.' This idea of repetition being helpful when learning a concept 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). Similarly, Student TA8 stated the importance of repeating the material for his personal understanding, even if the teacher already solved the problem in-class. He said: '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.'

Social knowledge building 1: Public statements. Stahl argues that it is not always possible to solve problems internally through a tacit pre-understanding. In that case, individuals may enter into a social process. During that collaboration process individuals need to articulate their pre-understanding through their text-based statements. During our study students either had public statements on the Voice Thread slides, in which they answered questions in the slide or ask a question about the content of the slide; or they had public statements in Google Documents, in which they communicated and collaborated to solve problems.

Student comments on Voice Thread slides were initially visible only to the teacher and the researcher, and then after the assignment due date those student statements were opened to the public. In her comment below, student TA20 explains how another student's question on Voice Thread and teacher's response in class 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: Yes 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. They were required to complete the problem solution explicitly in the document. Student contributions to the solution process are named as their public statements. During the analysis, sometimes both students' public statements were observed in the Google Document, but sometimes only one person's public statement was observed. 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 had positive comments about their group work. For example, Student TA6 explains how her interaction with other group members helped her to develop her personal comprehension of a 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.'

Social knowledge building 2: Argumentation & rationale, shared understanding, collaborative knowledge building. According to Stahl, individuals have their personal beliefs and those beliefs generate the socio-cultural knowledge through communication, argumentation, discussion, clarification and negotiation. In our study, during the group work for Google Document assignments, students did not necessarily display transformative processes that are suggested by Stahl such as: discussing alternatives, clarifying meanings, or negotiating perspectives. So, it was hard to analyze student argumentation and rationale. However, students mentioned that they completed those transformative 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. Below some exemplar student comments are given about students' use of chat panel.

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.'

Other interactions situated in Anderson's model.

Stahl's model focuses on the student-student interaction, communication, and collaboration; however it did not explain other components of the whole interaction processes that were present and had an unavoidable impact on the development of student-student interaction. To examine those interactions, a model that was developed by Anderson (2008) (see Figure 2) applied as the second model. 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 during this study. Anderson (2008)'s model is specifically used to investigate student-content and student-teacher interactions, which were reported by students as being among the influential factors on their learning and/ or attitude development. The student-student interaction component of Anderson's model is also not included here, since it is analyzed in detail above applying the Stahl's model.

Student-content interaction. Ertmer, Sadaf, and Ertmer (2011) suggest that common ways of student-content interaction is through the use of course readings, engagement with multimedia materials, or course assignments. 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 our research, two types of interactions developed between the students and the content through their participation in assignments via online tools. For the Voice Thread assignments, students interacted with the content by practicing problems using Voice Thread slideshows, and students interacted with their teacher and peers through the comments that they left on slides. Students also answered some questions during their practice, which enhanced and deepened their interaction with the content. For the Google Document assignments, students presented their mathematical thinking in written form through the Google Documents and solved mathematical problems by collaborating with their group members. Majority of students reported that Voice Thread practice problems which included answering questions during the practice helped them to understand the course material better. Some students also reported that they benefited from creating 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.

Anderson suggests that student-content interaction is more passive in online learning than the face-to-face instruction, but at the same time it offers some unique opportunities that are not possible in face-to-face form. One of the most important findings of this research revealed that using online tools in blended form made the passive structure of student-content interaction more active by requiring student input for the problem solutions. This feature was very beneficial for the students, but presentation of a problem slide by slide through Voice Thread also can be confusing as seen in a student comment below. The format of the Voice Thread can be also enhanced and modified based on their input. Some exemplar student comments for either case are presented below. Student TA21 and Student TA15 were explaining why they prefer Voice Thread to practice problems instead of textbook:

Student TA21: 'A book kind of explains it and then gives you problems. Voice Thread 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.'

Student TA15: 'As you go in to the book, a lot of people find it boring; but if you use the Voice Thread 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:

'Sometimes it was difficult using it (Voice Thread); 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… I think I really prefer to use my book. Voice Thread is a little complicated, and I am not very good at technology.

I just like having it all there.'

Teachers also visited student comments on the Voice Thread slides to correct misunderstandings and to make clarifications about the problem solution in the face-to-face sessions, especially before the exams. Those revisiting of student work on the online platform in face-to-face mode provided students an extra opportunity to fill in the gaps in their learning.

During their online work students had more time flexibility to reflect on their own understanding through their online participation in the problem solutions. At the same time sometimes they did not realize their misunderstandings, or could not find the correct solution as normally observed for all different types of technological tools. Interaction with their teacher in the face-to-face platform on their solution helped them in clarifying concepts they did not fully understand.

Student-content interactions through Voice Threads and the use of student comments in face-to-face sessions were a form of the *professional support* component of Anderson's model. In that case, Voice Thread presentations were used by students like interactive tutorials. Those interactive tutorials also provided students an *asynchronous communication* platform with their teacher and peers through the comments that they left on Voice Thread slides.

Student-teacher interaction. In this study, many students reported that they appreciated and found beneficial the mostly asynchronous and text-based communication with their teacher in addition to their face-to-face interaction, while a small percent of students had other expectations such as immediate responses from their teacher. For example, Student TA15 was explaining why he found it helpful having alternative communication options with teacher:

'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 Voice Thread and see your comment and reply to it.'

In his comment below, Student TA5 was explaining why asynchronous communication is not an effective way to interact with teacher for him:

'Even if you ask questions, she (teacher) is not going to answer it. So far I haven't seen much response from her…I have learned more through asking questions than she has actually taught us…she cannot be in front of the computer 24/7…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, gives a proper response. I can correlate it to the answer.'

Using Chat & Not Participating in the Google Document.

During this research, many students communicated through the chat panel in addition to the actual Google Document. This is quite surprising because they completed some of their argumentation, clarification and discussions through the chat panel; and used the actual document to present their outcomes. Additionally, it should be noted that some of those students did not participate in the Google Document assignments even through the chat panel. Originally these were was not a part of the primary research for the study. Therefore, during the implementation, student interviews were extended accordingly to investigate the reasons for using the chat panel and for not participating in the Google Document assignments. The findings related to these two interesting phenomenon are presented below.

Using Chat. One of the most attractive observations of this research is using chat which 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 their communication and discussion in the Google Document in the text form. However, starting from the training sessions, students discovered the chat panel on the side and completed most of their communication on the chat panel in addition to the actual document. Some important reasons that were given by students for using the chat panel included: actual document seems more formal; chat is faster, convenient; and communication with chat is neater. 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.' Some student comments stated that they did the clarifications, discussions and negotiations about the problem solution through the chat panel, so that they did not 'mess up' their document with the back and forth communications.

For some other groups, the chat panel was a place where they divided the solution process into small parts and they completed the solution cooperatively in the document. Student TA21 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.' At the same time, the students used an informal language, like using some slangs, in chat which made them feel more comfortable.

Not participating in the Google Document. As expected, some of the students preferred neither collaborating with their partner through the Google Document nor communicating via the chat panel. So another interview question asked the students why they did not participate. The most interesting reasons reported by students included: it is a new concept to use different communication tools for learning mathematics; their relationship with their partner was not good; they spent a lot of time on other classes and homework; procrastination; they have a preference for synchronous communication. Student TA4`s comment is a good example to explain why they did not participate in Google Document assignments:

'With computer it is kind of hard to transfer mathematics doing everything and typing it up I am not used to 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.'

Teacher comments were consistent with student comments in terms of interactions occurred when online tools were used by students for problem solving. Additionally, Teacher A talked about if she could provide more timely feedback to students, the Voice Thread presentations could be more effective:

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 Voice Thread.

Teacher B interestingly suggested that being assigned as partners for the Google Document assignments facilitated students' face-to face interaction with their group members:

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.

DISCUSSION

Modified Model

Based on the findings of this study, either only the Stahl's or the Anderson's model could not explain the findings, a modified framework is suggested below that combines Stahl's and Anderson's models (see Figure 7) for student communication, interaction, and collaboration.

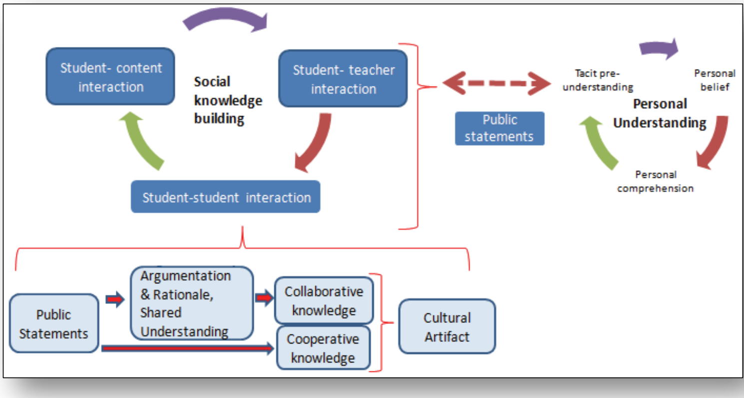


Figure 7. Modified model combining Stahl's and Anderson's models for student interaction, communication, and collaboration when online-tools are used.

Most of the components of this modified model are present in either Stahl's or Anderson's models. This new model embeds some components of Anderson's model into Stahl's model. This new model also suggests additional components and relationships that are not a part of either of those two models. Stahl artificially separates knowledge-building processes into two cycles as personal understanding and social knowledge building. The modified framework that is suggested here adds student-content and student-teacher interaction components of Anderson's model to the social-knowledge building process that is given in Stahl's model. This process was given in Stahl, but it was about the collaborative knowledge-building among students. In the modified model the whole process of knowledge construction by students is named as student-student interaction that was called as social-knowledge building by Stahl. The details about the discussion steps of social knowledge-building process are not analyzed different than the Stahl. Instead, this study examines the knowledge- building processes in two levels: the first level covers the possible interactions among the students, the content, and the teacher; at the second level this study investigates the structure of student-student interactions. This second level was called as social knowledge-building by Stahl and assumed to be collaborative in nature. This study suggests that this process could be either cooperative or collaborative.

One most prominent features of this modified framework is addition of the *cooperative knowledge* component. For some problems, students divided the solution of the problem into small parts and each person completed one part to solve the whole problem. Then each person demonstrated the solution to her/his part in the Google Document. Members of the same group had access to her/his solution anytime, since they had access to the same Google Document. For those problems that students worked on individually and then combined their solution pieces; students skipped the discussion, negotiation, and clarification steps and presented a *cooperative solution* to the problem instead of a *collaborative solution* as presented in Figure 7. 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).

On the other hand, for some other problems students communicated with each other, completed some argumentation, negotiation, clarification steps before arriving at a shared understanding; which is the process of developing a collaborative knowledge. Thus, the collaborative knowledge box also was kept in the new model, which was originally present in Stahl's model. However, as demonstrated at the bottom of the Figure 7, different students' public statements in a group generate and develop a group's cooperative knowledge; while collaborative knowledge is a result of some discussion processes not directly generated by the public statements. Either students had cooperative or collaborative knowledge construction, this process directly forms the cultural artifact.

Even if the *personal understanding* and *social knowledge-building* processes are represented with two separate cycles in Stahl's model; this separation is artificial. Two-way arrow between these two concepts represents the mutual interaction between these two processes. Stahl argues that individuals' perspectives generate their beliefs, and those personal beliefs become knowledge through social interactions. The findings of this current study are parallel with the model that is suggested by Stahl to conceptualize the mutual constitution of the individual and social processes of learning. Students articulated their personal understanding by their comments in Voice Thread presentations and their contributions in the Google Document assignments. These two concepts are named as public statements in this study. From the student interviews, we can tell that each group member's personal understanding was contributing to the social knowledge-building process during the Google Document assignments through both types of public statement. For some students their peers' statements in the Google Document (public statements in the social knowledge-building process) helped them to achieve comprehension of the content (personal understanding), which is consistent with the statement given by Stahl that neither personal understanding and social activity can exist without the other; and there is a two-way transaction between personal understanding and social knowledge building through public statements. In addition, the findings of this study revealed direct relationships between student-student, student-content, and student-teacher interactions. Thus, it can be suggested that all three types of interactions constitute the social construction of the knowledge, so should be included in the social knowledge building cycle.

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 related to student success in any virtual school because of their direct contact with students. In this study, mostly asynchronous, text-based communication occurred between students and teacher in addition to their face-to-face interaction. Such an unexpected trend was investigated that the majority of students appreciated and found beneficial the additional communication opportunities with their teacher. For some students, the idea of being able to reach their teacher online anytime reduced the stress that they have in class. They reported feeling lower pressure to ask questions during face-to-face sessions and they felt even more comfortable to ask questions online, since they are not being criticized by their classmates. Student comments on Voice threads were also revisited by teachers during the face-to-face sessions to clarify misunderstandings and for any extra explanations of the solution steps of the problems during they were working on the homework and projects on Google Documents. Bringing

Voice Thread 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. Reviewing the results of these observations indicates that student-teacher and student-content interactions had direct impacts on students' personal understanding and their contributions in the Google assignments. So that they are a part of the social knowledge-building process in the modified model and they have a two-way transaction with the personal understanding cycle.

Implications for Research and Practice

Roschelle, Patton, Schank, Penuel, Looi, & Dimitriadis (2011) argue that: 'good learning designs in CSCL can provide opportunities for students to co-construct ideas, while at the same time learning curricular disciplinary knowledge. The results of our study indicate that the co-construction could be in different forms, like cooperative and collaborative. CSCL research mostly emphasize 'co-construction of shared understanding' (Roschelle and Teasley ,1995; Dillenbourg, Järvelä, & Fischer, 2009) , similar to the way it is presented in Stahl's model. According to this point of view, learners enter to the collaboration cycle through the public statements, and then follow some steps such as argumentation and clarification, and they reach a shared understanding which ends with a collaborative knowledge and finally form the cultural artifact. However, our research suggests that cultural artifact not always has to be the result of a collaborative work, and could be the product of cooperation as well. This could be explained by the structure of the problems. The problems that students solved cooperatively in this study were more divisible and not necessarily require students to follow some argumentation steps such as discussions and negotiations. An informal discussion with an engineering professor (during the preliminary data analysis of this study) suggests that most of the engineering problems have the same divisible structure. The professor mentioned he plans to use the Google Documents for his classes as well after this discussion, since in engineering field it is an essential skill for students to solve a problem cooperatively. This specific finding of the current study may have implications for researchers and educators to design the problems accordingly depending on the purpose of the group work is assuring either *collaboration* or *cooperation* among students, and which skills they aspire their students to improve. It may also have implications for the theories of CSCL in terms of the meaning of the second 'C'. Follow up research be aimed to find out which problem structures and other conditions could support the co-construction of knowledge in *collaborative* or *cooperative* forms.

In CSCL literature, individual members of the groups are seen as additional learning resources in terms of contributing unshared prior knowledge to the discussion (Weinberger, Stegmann, & Fischer, 2010). Noroozi, O., Weinberger, A., Biemans, H. J., Mulder, M., & Chizari, M. (2012) points out that individual members' lack of knowledge may affect learning outcomes and additional information such as presentations about the given task can help to close the knowledge gap between the individuals. Findings of our research provide additional evidence for that prior study. Providing students the opportunity to monitor and correct their personal understanding through the continuous practice using Voice Thread presentations strengthened their problem solutions as a group in the Google Documents. This may imply that computer supported collaboration might have better results, if the use of communication and collaboration tools, like the Google Documents, are supported with the use of presentation tools, like the Voice Thread.

As demonstrated in the findings of this study, even if students surrounded by various technologies and use them frequently in daily life; they do not usually use them for learning, especially to solve mathematical problems. One aspect of this is that they used to learn mathematics with traditional methods, like teacher lectures and solving problems with paper and pencil; and rarely had a chance to explore other ways of learning mathematics. Thus, they are having hard time to adapt employing their technology skills in online environments. At the same time, they do not necessarily need to talk about their mathematical thinking in most of the learning environments. If they are required to participate and contribute in the online platforms, like the ones used in this study, they have to articulate their thinking and solution for the problem to their group members and the teacher which is an essential skill for them to have.

SUMMARY AND CONCLUSIONS

Findings of this study present a detailed analysis of the interaction, communication, and collaboration processes using online tools in blended form. Interactions were observed not only among the students; but student-content and student-teacher interactions were also observed. The modified model, which has been formed as a result of this research, suggests that student-content and student-teacher interaction have direct effects on student-students interaction; therefore they should be part of the social knowledge building process. The majority of the students appreciated for the extra communication opportunities with their teacher, while a small part of the students preferred face-to-face communication instead. The social-knowledge building process, when online tools are used, influences students' personal understanding as suggested by Stahl (2006).

As a result of detailed analysis of this research, the primary feature of using these types of online tools is that they helped students to develop the 21st-century skills that they need, like communication and collaboration skills; and also strengthened their justifying skills by participating in discussions, questioning each other's work in the problem solution process, and comparing ideas in the community of practice they developed. Students mentioned that this was a unique experience for them in terms of learning mathematics with online technology. In addition, some of them reported to use Google Documents for their other classes and in college. In this case, it is very 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.

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