

2017

Does Computer Use Matter? The Influence of Computer Usage on Eighth-Grade Students' Mathematics Reasoning

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Recommended Citation

Ayieko, R. A., Gokbel, E. N., & Nelson, B. (2017). Does Computer Use Matter? The Influence of Computer Usage on Eighth-Grade Students' Mathematics Reasoning. *FIRE: Forum for International Research in Education*, 4(1). Retrieved from <http://preserve.lehigh.edu/fire/vol4/iss1/5>

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Does Computer Use Matter? The Influence of Computer Usage on Eighth-Grade Students' Mathematics Reasoning

Abstract

This study uses the 2011 Trends in International Mathematics and Science Study to investigate the relationships among students' and teachers' computer use, and eighth-grade students' mathematical reasoning in three high-achieving nations: Finland, Chinese Taipei, and Singapore. The study found a significant negative relationship in all three countries between out-of-school computer usage of eighth-grade students and their mathematics reasoning scores. The study points to the fact that computer use out of school does not improve students' development of mathematics reasoning across the three contexts. Additionally, the more teachers had students use computer technology for higher-order thinking skills, such as for processing and analyzing data, the higher their mathematics reasoning scores in Finland, but the lower the students' reasoning scores in Singapore. The contrasting relationships in Singapore and Finland indicate the need to further study the nature of the activities related to computer use for higher order learning skills in the two countries. Implications for policy and research are further elaborated.

Keywords

Computer use, Hierarchical linear modeling, Large-scale studies, Mathematics reasoning

DOES COMPUTER USE MATTER? THE INFLUENCE OF COMPUTER USAGE ON EIGHTH-GRADE STUDENTS' MATHEMATICS REASONING

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Introduction

Technology usage in the 21st century has increased markedly in school and at home. The current role that technology plays has expanded from primarily entertainment to being an essential tool for classroom instruction. In the classroom, technology usage includes but is not limited to computers, smart boards, smart pens, and calculators. These advances in technology are important for teaching science, technology, engineering, and mathematics (STEM) related courses and are intended to increase students' access to mathematics and science (Common Core State Standards for Mathematics [CCSSM], 2010; National Council of Teachers of Mathematics [NCTM], 2014). Particularly, these technologies allow students to make more sense of the underlying concepts in mathematics as well as promote students' reasoning skills (NCTM, 2014).

Problem solving and critical thinking is essential for the complex society of the 21st century. The unique challenges brought about by the changing societies as they embrace new interactions in the community and workplace require that graduates have deeper skills than just applying skills learned through memorization. Teaching students these skills means that teachers have to modify their instruction and has been shown to be challenging (Saavedra & Opfer, 2012; Silva, 2009). Mathematics is one of the subjects that require students to engage in problem solving, critical thinking, reasoning, and technology integration (CCSSM, 2010; Greiff et al., 2014; NCTM 2014; Smith & Stein, 2011). Indeed, technology use in teaching and learning these higher order skills is one of the recent developments in education (Saavedra & Opfer, 2012). "Technology allows students to transfer skills to different contexts, reflect on their thinking and that of their peers, practice addressing misunderstandings, and collaborate

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with peers” (Saavedra & Opfer, 2012, p. 9). However, the emphasis and technology integration in teaching and learning high order skills in mathematics differs across contexts (e.g., Mullis et al., 2012).

Scholars have found technology to be an essential resource for use in instruction. For instance, technology can be an effective tool for motivating students (Ertmer & Ottenbreit-Leftwich, 2010) and in particular, useful for improving students’ mathematical achievement (e.g., Barrow, Markman, & Rouse, 2009; Demirbilek & Tamer, 2010; House & Telese, 2012; NCTM, 2014; Van den Heuvel-Panhuizen et al., 2013; Wittwer & Senkbeil, 2008). Of particular importance is the use of computers because of the application in various subjects such as mathematics, science, and reading. Recent studies on teachers’ and students’ computer use document (i) computer use at home (e.g., House & Telese, 2012; Wittwer & Senkbeil, 2008; Vekiri & Chronaki, 2008), (ii) computer gaming (e.g., Demirbilek & Tamer, 2010), (iii) computer aided instruction (e.g., Barrow, Markman, & Rouse, 2009), and (iv) web usage (e.g., Loong & Herbert, 2012). Taken together, these studies indicate that computer usage has had a positive influence on student learning. However, to further examine the relationship between technology use and its associations to students’ mathematics reasoning will further justify the importance of the unique advantages on technology integration for learning mathematics for understanding.

The relationships between computer usage and students’ academic achievement are influenced by several factors, such as culture, grade level, selection of tasks, and teachers’ knowledge (Loong & Herbert, 2012; Vekiri & Chronaki, 2008). Although the factors studied provide information for the improvement on policy decisions for learning and instruction, these studies are limited to relationships between computer usage and general mathematics achievement. Missing from these studies is literature on how these factors influence achievement in particular students’ cognitive competencies in mathematics. With the problem-solving demands of the 21st century, students must be able to reason, think critically, and engage in problem solving.

The purpose of this study, therefore, is to examine the relationship between the use of computers for learning mathematics and eighth-grade students’ reasoning skills in mathematics. The study seeks to identify how the use of computer technologies and computer software in teaching and learning is related to eighth-grade students’ reasoning in mathematics in Finland, Chinese Taipei, and Singapore. The three countries were selected because of the consistent high mathematics achievement of their eighth-grade students in the international assessment such as the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Students’ Assessments (PISA). Although the students in these three countries post high scores in mathematics they have different policies governing the use of Integration of Computer Technology (ICT) in mathematics teaching and learning. As such, the comparative findings from these nations are useful for informing education policy related to the possible influence of ICT for learning mathematics in these nations.

Related Literature

The use of technology for learning mathematics can occur at home, school, and in many other places. To effectively learn mathematics, however, teachers should know not only which technological tools are appropriate, but also how and the frequency of their use, and access to adequate supplementary support. With a focus on computer usage, this section provides information on the influence of where and how students and teachers use computers on students’ mathematics achievement. The literature cited is organized to first include studies on students’ use of computers at different locations before reviewing literature on teachers’ use of

computers and related support and *comfortability* in mathematics instruction. Following is literature on recent large-scale studies on computer use. Finally, the section ends with computer use and students' mathematics reasoning.

Students' Use of Computer

At home. Students' use of computers at home influences their mathematics achievement in varied ways. For example, Wittwer and Senkbeil (2008) found no links between 15 year old students' home computer use and their mathematics achievement in Germany. The authors identified four different user profiles: "the smart users, the rational users, the recreational users, and the indifferent users" (Wittwer & Senkbeil, 2008, p.1566). The smart users were confident and interested in computer use; and were primarily engaged in word processing, finding homework support, playing games, conducting research, and communicating with others. However, the rational and recreational users had less overall interest in using computers at home, but still found them engaging to a certain extent. The recreational users spent time watching movies, playing games, or listening to music (Wittwer & Senkbeil, 2008). Wittwer and Senkbeil found a positive relationship between students' use of computers for problem solving activities and mathematics achievement. Similarly, O'Dwyer, Russell, Bebell, and Seeley (2008) found no relationship between fourth grade students' home technology use and mathematics achievement. The home technology use was categorized: Recreational uses and academic uses. Specifically, recreational uses of technology include using home computers for playing games, searching the Internet for fun, chatting, emailing, and creating Mp3/music, whereas academic uses of technology represent using the internet for mathematics related schoolwork and writing papers for mathematics class (O'Dwyer et al., 2008).

Studies on the effects of how long students spend on the computer at home show mixed results. Some studies suggest that students who use a home computer almost every day obtain higher scores in mathematics compared to those who use the computer less than once a month (e.g., Wittwer & Senkbeil, 2008). Another study, however, shows that too much time spent on a computer at home can cause a decline in student achievement (Lei & Zhao, 2007). Students who spent less than three hours daily on the computer had a higher mean grade point average (Lei & Zhao, 2007). Lei and Zhao (2007) suggested three hours per day to be a critical point for the length of time students should use computers. These two studies focus more on time spent on the computer at home, identifying the activities that students do, and categorizing computer use in the home. In sum, students' computer use at home is varied and the different uses can support students' learning. Perhaps a replicate study on the relationship between, students' computer use at home on specific cognitive domains in mathematics could provide further insights.

At school. Students' computer use in school differs by the extent and type, and has different relationships with students' mathematics achievement. Results from the 2009 National Assessment of Educational Progress (NAEP) showed that more than three-quarters (76%) of eighth-grade students never or hardly ever used a computer for math learning at school in the United States. Students may use computers at school, (i) as a *production software*, including word processing, spreadsheets, draw-paint graphics, presentation, authoring, concept mapping, and planning, (ii) an *internet or research software*, including Internet browser, CD reference materials, and communications, and (iii) an *educational software*, such as drill-practice-tutorial, problem solving, and process software (Inan, Lowther, Ross, & Strahl, 2010; p. 542). Inan et al. (2010) found that word processing programs, Internet browser, and presentation programs were three most common types of computer use during classroom instruction.

Computer usage at school is influential in improving students' success in mathematics but also challenging for teachers' classroom management. Eyyam and Yaratan (2014) found the use of technology in the classroom had a positive impact on secondary school students' success and attitudes in mathematics. An earlier meta-analysis of 46 studies conducted by Li and Ma (2010) found significant positive effects of computer technologies on students' mathematics achievement in K-12 classrooms in the United States. In particular, students' computer use had a greater influence in fostering mathematics achievement among elementary compared to secondary school students (Li & Ma, 2010). In contrast, Song and Kang (2012) found a negative relationship between technology use and middle school students' mathematics achievement. In sum, the use of computers to learn mathematics in school can certainly be of benefit to learners, but may also have a negative influence on student behavior depending on the selected activities. In these studies, the researchers emphasize on the students' computer use and the relationships to students' learning as was later proposed by McKnight and colleagues (2016). However, the cognitive competencies afforded by computer use at school is not explicate in these studies.

Teachers' Computer Use

Teachers use computers for different purposes and ways. Their computer use is influenced by the amount of support they receive and their comfort levels. Hughes (2005) classified teachers' computer use as: replacement, amplification, and transformation. The replacement category involves using technology without altering any instructional goals or learning processes. Technology as amplification implies efficient and effective use while maintaining the same tasks for the activities. In contrast, transformation of technology may change the teachers' role in the classroom and the learning support the teachers provide. Additionally, Tondeur, van Braak, and Valcke (2007) categorized teachers' instructional uses of computers: *an information tool*, *a learning tool* and *for basic skills*. Other scholars noted that teachers use computers for assessment and feedback, to promote students' collaborations, and to foster the development of students' skills. (Scherer, Siddiq, & Teo, 2015). Teachers' use of computers in mathematics instruction is influenced by several factors: availability of technological devices, technical support, and comfort level (Hartsell, Herron, Fang, & Rathod, 2010). In each of these categories of technology use, computer use served as a resource for support for teaching and learning mathematics. Thus, the supports and comfort that teachers have for computer use serves as effective mechanisms for learning and efficiently using the computer as an instructional tool.

Computer Use and Reasoning

Mathematics reasoning. Reasoning in mathematics is “the ability to contextualize-to abstract a given situation and represent it symbolically...considering the units involved; attending to meaning of quantities” (CCSSM, 2010, p. 6). The NCTM reasoning and proof standard states that students should be able to “make and investigate mathematics conjectures, develop and evaluate mathematical arguments, and select and use various types of reasoning (NCTM, 2000, p. 56). Mullis, Martin, Ruddock, O'Sullivan, and Preuschoff (2009) defined reasoning as the cognitive domain of mathematical learning outcomes that include possessing strong analytical skills as well as having the ability to generalize, integrate, justify results, and solve non-routine problems. Reasoning represents a valuable outcome of mathematics education in view of its connections to students' ability to think logically and systematically (Mullis, Martin, & Foy, 2005). Indeed, reasoning in mathematics enables students to apply content specific knowledge in a variety of ways and also leads to a deeper understanding of specific mathematics.

Computer technologies support students by helping them focus on decision-making, reflection, reasoning, and problem solving in different content strands of mathematics (NCTM, 2014). In addition, technology integration in teaching allows for more access to knowledge, support from instructors, and collaboration with peers and virtual communities (Dede, 2008). Sethy (2012) found that learning through computer technology in Turkey enabled students to think rationally and to engage in problem solving. The findings from these studies support the notion that the use of computers for learning mathematics is related to mathematics reasoning. However, there is a need to examine if these relationships hold across different cultural contexts in the current technology era.

Large-scale Studies on Computer Use and Students' Achievement

Results on the influence of computer use in students' achievement using large-scale studies are mixed. Using the Program for International Assessment in Education (PISA-2006) data, Spiezia (2011) found a positive significant effect on the relationship between students' computer use and their science achievement. Similarly, students' exposure to ICT at home and school was a strong predictor of ninth grade students' mathematics achievement (Delen & Bulut, 2011). However, technology uses in school and for entertainment were found to be negative predictors of students' mathematics achievement in Chinese Taipei, Singapore and Finland (Petko, Cantieni, & Prasse, 2016). Most of the recent studies with large-scale studies draw from the PISA data. Kadujevich (2015) emphasized on the need for large-scale studies focused on the influence of computer use on mathematics achievement and suggested TIMSS as a quality data set.

The available research evidence demonstrates that scholars have studied the influence of technology integration on general mathematics achievement. Computer use and the relationships with particular cognitive domains focused on higher order thinking are scant in the literature. More specifically, with the emphasis on problem solving and reasoning emphasized in the 21st century competencies, the relationships between teachers' computer use and students' mathematics reasoning should be included in the conversation.

Conceptual Framework

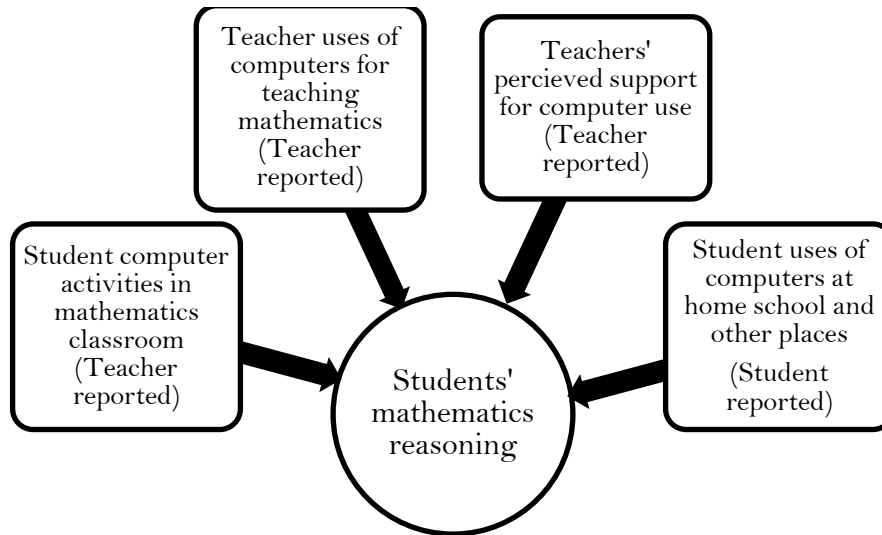
In this study, technology use was examined in terms of both quantity and type of integration. The quantity of technology use was measured by the frequency of technology use of students at different places such as, home, school, and other places. The technology integration was examined by analyzing technology use by teachers and students during mathematics instruction.

Hughes's (2005) proposed types of computer integration in instruction: replacement, amplification, and transformation. Later, Tondeur et al. (2007) suggested several categories of instructional uses of computers including an information tool, a learning tool and for basic skills. Based upon, and modified from, those taxonomies of instructional technology, technology use in this study was categorized based on the role of technology use: Teacher's use of technology (basis of instruction and as a supplement), and computer activities during mathematics instruction (exploring mathematics principles and concepts, practicing skills and procedures, looking up ideas and information, and processing and analyzing data). Finally, several important factors that influence teachers' use of computers in mathematics instruction that include adequate support and feeling comfortable with technology, were investigated in this study drawing from a study by Hartsell and colleagues (2010).

A summary of the proposed relationships of the variables in the study is presented in Figure 1. The hypothesized relationships are based on the cited literature that focuses on the relationships between computer usage by students and their teachers, and students'

mathematics reasoning. Specifically, we hypothesize that computer use is related to students' reasoning in mathematics. Figure 1 presents the variables selected from the TIMSS 2011 database that mirror the relations examined in the study and are informed by the cited literature.

Figure 1: Proposed relationships between the Computer use by teachers and students, and students' mathematics reasoning



This study used TIMSS 2011 data to investigate the relationships between computer use for learning mathematics, and eighth-grade students' reasoning in mathematics in Finland, Chinese Taipei, and Singapore. The questions guiding the study are:

- R1:** What are the differences in the extent of computer usage by eighth-grade students and their teachers in Finland, Chinese Taipei, and Singapore?
- R2:** What are the differences in the level of support and *comfortability* in computer use for the students' teachers in the three countries?
- R3:** Are there significant differences in eighth-grade students' reasoning in mathematics across the three countries?
- R4:** What are the patterns of the relationships between eighth-grade students' computer use (at home, school, and other places) and their mathematics reasoning in the three countries?
- R5:** What are the patterns of the relationships between eighth-grade teachers' computer use and their students' mathematics reasoning?

Methods

Data and Participants. The data used in this study is from the 2011 TIMSS database. TIMSS is an international assessment administered to a representative sample of fourth graders and eighth graders every four years from 1995 to date. TIMSS 2011 was the fifth international assessment with 63 countries participating. The students and their teachers responded to the survey questions and students also took the mathematics and science assessments. The items selected for this study were obtained from the mathematics teacher questionnaires that inquired about the backgrounds, attitudes, teaching activities, and

approaches of the students' teachers. The teachers in the TIMSS 2011 are the teachers of nationally representative samples of students and are not representative samples of teachers in the participating countries (Kastberg, Roey, Ferraro, Lemanski, & Erberber, 2013). Because the students must be linked to their respective teachers when analyzing teacher data, teachers are referred to as the students' teachers. Therefore, in the following sections, the teachers represent the eighth grade students' teachers. A summary of the participants in the study is provided in Table 1.

Table 1: Participants in the study.

Country	Number of students	Number of Teachers
Singapore	5927	330
Chinese Taipei	5042	162
Finland	4266	250

Context. The promotion of technology usage in teaching and learning has been a cross-national focus throughout the last decade. With a particular focus on the three selected countries, a brief description of the country education information is necessary. The Organization for Economic Co-operation and Development (2015) reported a huge gap amongst Finnish students between their use of new technologies in their everyday school lives and their lives outside of school. The identified gap in the Finnish Education System led to the establishment and launching of Integration of Computer Technology (ICT) in schools in 2010 (Niemi, Multisilta, Lipponen, & Vivitsou, 2014). Similarly, technology use in education is one of the primary goals of the Ministry of Education in Taiwan (Young & Ku, 2008). Students are required to take computer literacy classes and collect data from the Internet. In addition, some topics in mathematics are taught using technology especially geometry (Mullis et al., 2012).

In Singapore, three major initiatives have been launched since 1997: the first Masterplan (1997-2002) developed a strong infrastructure and provided equipment for schools to employ ICT; the second Masterplan for ICT in Education (2003-2008) improved this foundation by promoting the effective use of computer technology in education; and the third Masterplan (2008-2013) focused on enriching the learning environments of students and supporting their gain of knowledge (Infocomm Development Authority of Singapore [IDAS], 2008). These goals/plans serve as guides and expectations for teaching mathematics. Across these contexts, it is evident that there has been an increased emphasis on computer usage in instruction. These three countries show an increased emphasis on technology integration in education and thus beg for further studies on whether these initiatives are influential in the higher mathematics achievements and development of higher order thinking.

Variables

The students responded to questions that sought information about their home backgrounds, attitudes, and experiences in mathematics classes. The study focused on responses to students' and teachers' experiences with computer use and the mathematics reasoning scores of the eighth-grade students. Following is a description of the items examined in this study.

Independent variables. The following students' background variables were used as covariates in this study. Covariates are important inclusion because they serve as control variables in relational studies so that "the true influence of the independent variable can be determined (Creswell, 2009, p.51)".

Socioeconomic factors. The socioeconomic status variables include the *parental level of education* and *number of books in the students' home*. These variables are referred to as the students' academic resources (Carnoy, 2015). Students selected the highest level of education attained by their parents that were set using the International Standard Classification of Education (ISCED). Students were also asked to report the number of books (excluding school textbooks, newspapers, or magazines) in their home. Responses were provided on an ordinal scale: 1-none or very few (0–10 books), 2-enough to fill one shelf (11–25 books), 3-enough to fill one bookcase (26–100 books), 4-enough to fill two bookcases (101–200 books), and 5-enough to fill three or more bookcases (more than 200).

Gender. Gender was also included in the analysis as a background variable and was recoded as a dummy variable with female equal to 1 and male equal to 0.

Computer use. Computer use was the primary independent variable and examined in two main categories: 1) students' use of computers in different places, and 2) teachers' use of computers including instructional computer activities and perceived support and comfortability for technology integration.

Computer use by students. The eighth-grade students were asked to indicate how often they use computers at home, school, and at other places with responses set to an ordinal scale: 1-every or almost every day, 2-once or twice a week, 3-once or twice a month, or 4-never or almost never.

Computer use by teachers. The teachers responded to questions from the teacher questionnaire to investigate their use of computers in teaching mathematics. They selected from three options: as a basis of instruction, as a supplement, and not used. This item was recoded as two dummy variables. In one dummy variable, responses where computers served as the basis of instruction were coded as 1 with all other observations coded as 0. For the second dummy variable, responses in which computers were used as a supplement had observations coded as 1 with all others coded as 0. This coding system allowed for the use of computers as basic instruction and a supplement to be compared against not using the computer at all.

Computer activities. The teachers reported how frequently they had students engage in certain computer activities during mathematics lessons. The listed activities included: (i) *Explore mathematics principles and concepts*, (ii) *Practice skills and procedures*, (iii) *Look up ideas and information*, and (iv) *Process and analyze data*. The teachers' responses about the activities they had the students engage in were set to an ordinal scale: 1-every or almost every day, 2-once or twice a week, 3-once or twice a month, or 4-never or almost never.

Support in using computers in classroom instruction. Teachers were also asked to indicate their level of agreement with the following statements: (a) *I feel comfortable using computers in my teaching*, (b) *When I have technical problems, I have ready access to computer support staff in my school*, and (c) *I receive adequate support for integrating computers in my teaching activities* (Foy, Arora & Stanco, 2013, p. 247). Their responses were given on a likert scale: 1-disagree a lot, 2-disagree a little, 3-agree a little, and 4-agree a lot. These items were summed to form a composite variable named "*comfortability and supportive environment*", referring to their comfortability in using computers and support the teachers' receive to use computers.

Dependent variable. Eighth grade students' mathematics reasoning scores was the dependent variable in this study. In the TIMSS 2011, the framework for mathematics assessment had two distinctive dimensions: content and cognitive dimensions. The content dimension specified the subject matter to be assessed and was categorized under four content domains: (a) number, (b) algebra, (c) geometry, and (d) data-and-chance. The cognitive domains were classified: (a) knowing, (b) applying, and (c) reasoning. 'Knowing' refers to the knowledge

of facts and procedures; ‘applying’ means the use of knowledge to solve routine problems; and ‘reasoning’ represents transferring knowledge and applying mathematical thinking to novel and complex problems (Mullis et al., 2009). This study focuses on the reasoning domain of the cognitive dimension on the eighth-grade achievement test. This subscale score of the eighth-grade students’ mathematics achievement, in this case the students’ reasoning score, was available in the form of five plausible values in the TIMSS database.

Analysis

Descriptive analyses were used to show the extent of computer use by students and their teachers in the different countries, as well as the teachers’ perceived support to address the first and second research questions. A mean differences analysis was conducted using the International Data Explorer (<http://nces.ed.gov/surveys/international/ide/>) to answer the third research question seeking if there are significant differences in students’ reasoning in mathematics across the three countries.

For the fourth and fifth research questions, a predictive analysis was performed to illustrate how the students’ and teachers’ computer use, and teachers’ comfortability and support predict student reasoning in mathematics in the selected countries. Due to the clustered nature of the data, a multi-level modeling technique was appropriate. The students and their teachers were sampled using a two stage sampling process. In the first stage the schools within a country were randomly sampled from each region or using an agreed upon demographic variable. Intact classes were sampled from each of the sampled schools in the second stage. During the sampling process, the non-participation of schools and classes was accommodated for during the sampling process by the inclusion of weights. It should be noted that teachers were not sampled in this two-stage process, but were instead considered as attributes of the students in the sampled classes. Therefore, when analyzing the data the students are the units of analysis, and the teachers are then attributes of the students. For this reason, the students’ background and their computer use were set at level one and the teachers’ responses set at level two in the multilevel model. The study used the students’ background factors as covariates, which included socioeconomic factors and gender. The international database (IDB) analyzer, which is a “plug-in” used on the SPSS platform and the HLM software were used in these analyses because it takes the clustering effect, the weighting of the samples, and the students’ achievement in plausible values can be incorporated using this software.

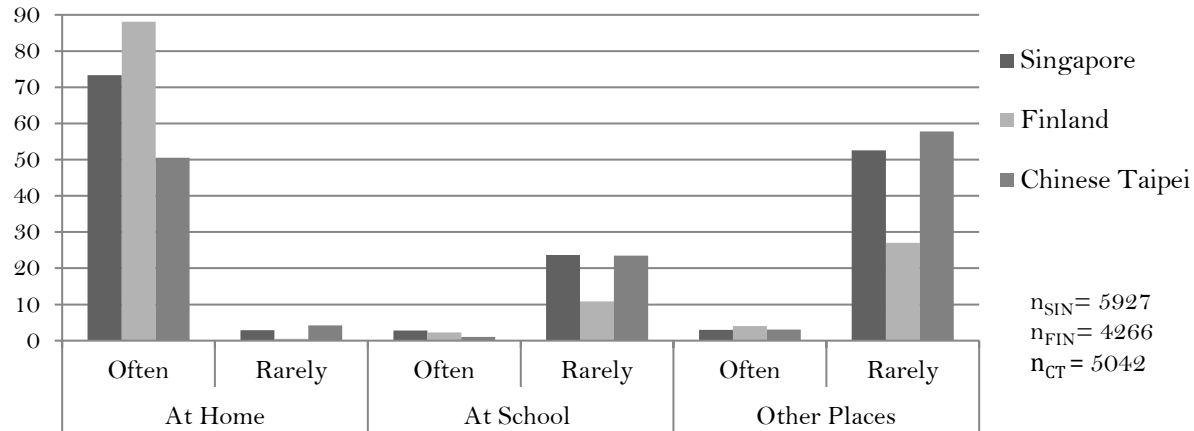
Results

This section first presents the descriptive results showing how eighth grade students and teachers use technology, and the extent teachers have support and a comfortable environment for technology integration (research questions 1 and 2). Second, the significance test for the differences in the eighth-grade students’ mathematics reasoning is reported. Third, the multi-level models of the relationships between computer use and eighth grade students are presented.

Students’ Computer Use. Across the three countries, the extent of students’ computer usage varies by location. Figure 2 presents the extent of their use of computers at home, in school, and in other places. Finland had the highest percentage of students using computers almost every day at home (88.14%), whereas Chinese Taipei had the lowest percentage (50.56%). Students from Chinese Taipei reported the highest percentage of computer use at school once or twice a week (68.25%), whereas Singapore showed the lowest percentage at 34.57%. Chinese Taipei had the highest percentage of students who reported that they rarely use computers use in other places. Students in Finland (40.53%) reported that they used

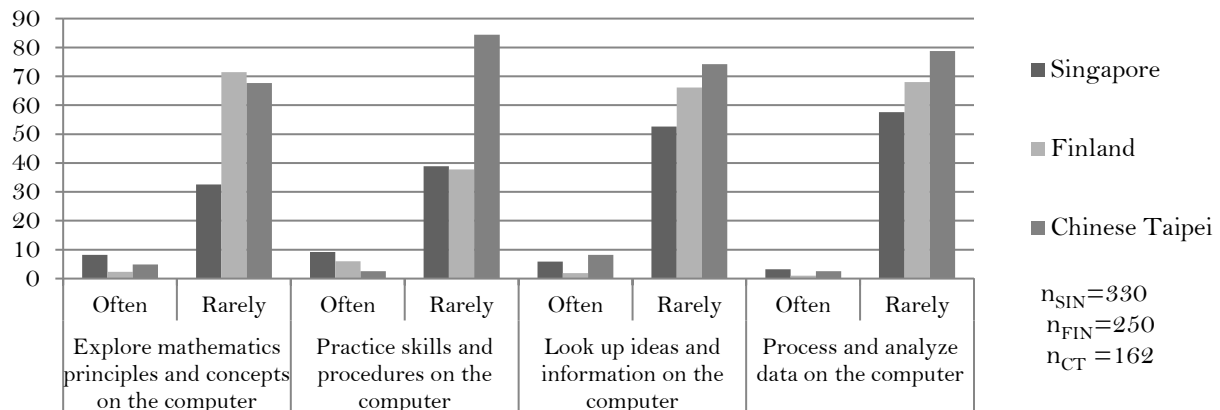
computers in other places more than once a month, but 57.81% of the students in Chinese Taipei reported they hardly used the computers in other places.

Figure 2. Extent of students' computer usage at home, school and other places.



Often represents *every day or almost every day*; *Rarely* represents *never or almost never*.

Figure 3. Teachers' reports on the frequency of engaging students in selected computer activities during mathematics lessons.



Computer Use in Instructional Activities by the Eighth-Grade Teachers

The instructional activities in which the teachers used computers varied across the selected countries. Less than 10 percent of the students' teachers in the three countries used computers to practice skills and procedures (9.19% in Singapore, 6.04% in Finland, and 2.51% in Chinese Taipei.) often. In particular, 78.78% of the eighth-grade teachers in Chinese Taipei rarely had their students use computers to process and analyze data, and 71.46% of teachers in Finland reported rarely having students explore mathematics principles and concepts on the computer. Of the three countries the Singaporean teachers reports indicate they engaged their students in the four computer activities occasionally² and at a higher frequency than Finland and Chinese Taipei. Processing and analyzing data was an activity that all teachers in the three

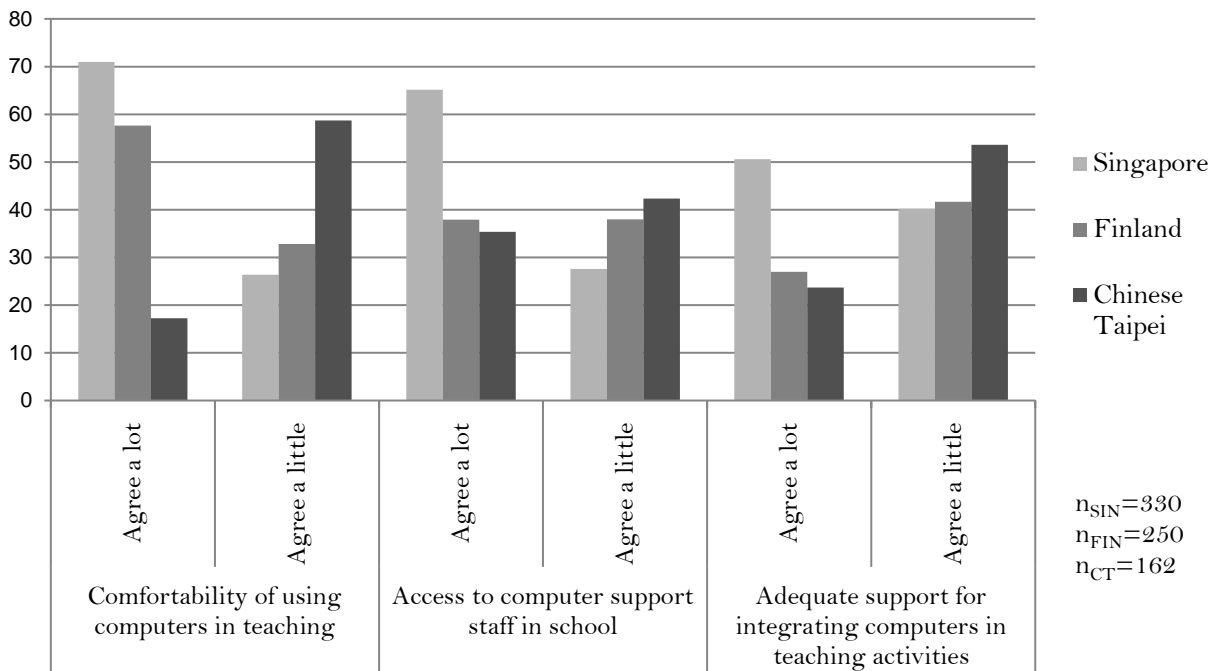
² Occasionally refers to once or twice a week or once or twice a month. In this article occasionally is also referred to as at least once a month.

countries engaged in the least amount of the time among the four activities. A summary of the students' teachers' computer usage for the selected mathematics activities across the three countries is presented in Figure 3.

Comfortability and Support in Computer Use in Mathematics Instruction

There were differences in the level of support for computer use and “comfortability” of computer use during mathematics lessons among the three countries. In particular, a majority of the teachers in Singapore (71.01%), and Finland (57.61%) strongly agreed they were comfortable to use computers in teaching mathematics; however, only 17.24% of teachers in Chinese Taipei held this opinion. Additionally, 65.14% of the teachers in Singapore strongly agreed that they had access to computer support staff in school, but less than half of the teachers in Finland (37.89%), and Chinese Taipei (35.37%) agreed with this sentiment. Approximately half of teachers in Singapore (50.62%) reported they had adequate support for integrating computers in teaching activities; a minority of teachers Finland (26.97%), and Chinese Taipei (23.66%) reported the same. Figure 4 presents a summary of the teachers' responses regarding their comfort level and support for integrating computers in mathematics instruction.

Figure 4: Eighth-grade teachers' level of agreement on support and “comfortability” in computer use for classroom instruction.



Summary of descriptive findings. The frequency of computer use by the students and teachers in the three selected countries are varied. Particularly, students in Finland used computers more frequently at home and in other places than the students in Singapore and Chinese Taipei. The reports from the students indicate that in all three countries, computers were used in the schools occasionally. However, a focus on computer use among the students' teachers suggest that the Singaporean teachers were the most supported and comfortable in using computers in instruction and also used computers in selected activities the most, when

compared to the other two countries. The Singaporean and Finish teachers engaged their students more frequently in using computers for lower orders activities such as exploring mathematics principles and concepts and practicing skills and procedures. Finally, among the three countries the teachers in Chinese Taipei engaged students in computer use in mathematics activities the least.

Differences in reasoning scores. A mean differences analysis was conducted to answer the third research question. This test was used to analyze if the mean mathematics reasoning scores across the selected countries were significantly different. Eighth-grade students' reasoning scores were significantly higher in Chinese Taipei than in Finland ($p < .001$). Similarly, the Singaporean students' reasoning scores were significantly higher than the reasoning scores of the students in Finland ($p < .001$). However, there was no significant difference in the reasoning scores between students in Chinese Taipei and Singapore. A summary of the mean differences is presented on Table 2.

Table 2: Differences in Reasoning Scores across Four Countries.

(I) Country	(J) Country	Mean Difference (I-J)	Standard Error
Chinese Taipei	Singapore	4.6	5.5
Chinese Taipei	Finland	97.2***	4.4
Singapore	Finland	92.6 ***	5.1

* $p < .05$, ** $p < .01$, *** $p < .001$.

Relationships between Computer Use and Students' Reasoning in Mathematics

The multi-level models of the relationships between computer use and students' reasoning are discussed in this section. The model summaries for the unconditional model, the model of the relationships between students' computer usage and their mathematics reasoning, and the model of the relationships between teachers' computer usage and their students' mathematics reasoning are presented in Tables 3, 4, and 5 respectively. The equations presented are the mixed models with the level one and level two variables combined in one equation. (Adapted from Lee and Bryk, 1989)

Unconditional model

$$\text{BSMREA01}_{ij} = \gamma_{00} + u_{0j} + r_{ij}$$

Singapore had the highest percentage of variation accounted for by the clustering at 73%, whereas Chinese Taipei and Finland reported much lower intra-class correlation coefficients (ICC). Specifically, 21% and 24% of variation in mathematics reasoning was between the teachers in Chinese Taipei and Finland, respectively. Equation 1 and 2 are the multilevel models of the relationships between computer use and mathematics reasoning in this study.

Model of eighth grade students' computer use and their mathematics reasoning (Level 1)

$$\begin{aligned} (\text{Math reasoning})_{ij} = & \gamma_{00} + \gamma_{10} * (\text{Students' number of books at home}) + \gamma_{20} * (\text{Students' mother} \\ & \text{level of education}) + \gamma_{30} * (\text{Computer use at home}) + \gamma_{40} * (\text{Computer use at} \\ & \text{school}) + \gamma_{50} * (\text{Computer use at other places}) + \gamma_{60} * \text{FEMALE}_{ij} + u_{0j} + r_{ij} \end{aligned}$$

Table 3: The Unconditional Models of Students' Mathematics Reasoning in the Three Countries.

Variables	Singapore	Chinese Taipei	Finland
Intercept	602.57*** (4.74)	605.62*** (4.31)	505.01*** (2.66)
<i>Variance components</i>			
Intercept u_0	6790.11	2289.11	1413.39
Level 1 r	2570.83	8526.49	4529.95
ICC	0.73	0.21	0.24
Chi-Square	15763.19	1532.66	1412.19
Level 1 (n)	5927	5042	4266
Level 2(n)	330	152	258

*** $p < .001$

Model of the eighth grade students' teachers' computer use and students' mathematics reasoning

$$\begin{aligned}
 (\text{Math reasoning})_{ij} = & \gamma_{00} + \gamma_{01} * (\text{Basis for instruction}) + \gamma_{02} * (\text{Supplement for instruction}) + \\
 & \gamma_{03} * (\text{Comfortability and supportive environment for teachers}) + \\
 & \gamma_{04} * (\text{Explore mathematics principles and concepts}) + \gamma_{05} * (\text{Practice skills} \\
 & \text{and procedures}) + \gamma_{06} * (\text{Look up ideas and information}) + \gamma_{07} * (\text{Process and} \\
 & \text{analyze data}) + \gamma_{10} * (\text{Students' number of books at home}) + \\
 & \gamma_{20} * (\text{Students' mother level of education}) + \gamma_{30} * \text{FEMALE}_{ij} + u_{0j} + r_{ij}
 \end{aligned}$$

Students' computer use and mathematics reasoning. As mentioned in earlier sections of this report, students' use of computer occurs in school, at home, and other places. A summary of the relationships between their computer use and mathematics reasoning is presented in Table 4. In all three countries, more computer usage by the eighth-grade students in other places was related to a significantly lower mathematics reasoning score. The relationships between students' computer use at home and their mathematics reasoning differs in the three countries. Notably, in Chinese Taipei, computer use at home was significantly related to a lower mathematics reasoning score ($\beta_{\text{Chinese Taipei}} = -3.72$, $p < 0.01$). The relational patterns in Singapore ($p = 1.29$) were in opposite directions to Chinese Taipei and Finland ($p = 0.93$). Similarly, there was a significant negative relationship between students' computer use at school and their mathematics reasoning in Chinese Taipei ($\beta_{\text{Chinese Taipei}} = -6.15$, $p < 0.05$), whereas the relationship patterns in Singapore ($p = 0.57$) positive but negative in Finland ($p = 0.97$).

Eighth grade teachers' computer use and students' reasoning. The relationship patterns between the eighth grade teachers' computer use and their students' mathematics reasoning differs in the three countries. A summary of the predictive analysis for each of the three countries is discussed. Table 5 presents the multi-level model of the relationships between computer usage of the students' teachers and the eighth-grade students' reasoning scores.

Table 4: Relationships between Students' Computer Use and Students' Reasoning in Mathematics in the Three Countries.

Variables	Singapore	Chinese Taipei	Finland
<i>Intercept</i>	602.87*** (4.71)	608.97*** (4.25)	506.60*** (2.59)
<i>Background variables</i>			
Gender (female)	-12.87* (4.03)	-8.37* (3.21)	-3.80 (2.40)
Number of books in the home	0.96 (1.32)	19.64*** (1.36)	13.86*** (1.10)
Mothers level of education	-0.50 (0.63)	1.06 (0.98)	0.76 (0.80)
<i>Student use of computers</i>			
At home	1.92 (1.49)	-3.72** (1.88)	-3.05 (3.28)
At school	0.78 (1.38)	6.15* (2.94)	-1.85 (1.90)
Other places	-6.75* (1.56)	-15.82*** (1.83)	-12.63*** (1.90)
<i>Variance Components</i>			
Level-2 between group <i>SD</i> (<i>u0</i>)	81.99	47.07	36.79
Level-1 within group <i>SD</i> (<i>r</i>)	50.05	85.99	64.12
Level 1 (n)	5927	5042	4266
Level 2(n)	330	152	258

* $p < .05$, ** $p < .01$, *** $p < .001$

Singapore. The relationship between computer use as a basis for mathematics instruction was positively related to students' mathematics reasoning ($p=1.23$) in Singapore, but the relationship between computer use as a supplement and students' mathematics reasoning was negative ($p=.06$). Additionally, teachers level of support and comfortability had negative relationships with students' mathematics reasoning ($p=.44$). Notably, three mathematics activities the students' teachers engaged in were positively related to their students' mathematics reasoning, but were not significant (explore mathematics principles and concepts, practice skills and procedures and look up ideas and information). However, the more the teachers had their students use computers to process and analyze data, the lower their mathematics reasoning ($\beta_{\text{Singapore}} = 46.54, p < 0.05$).

Chinese Taipei. The use of computers as a supplement for teaching was positively related to students' mathematics reasoning ($p=.06$). Further, the students' teachers' comfortability and supportive environment was positively related to students' mathematics reasoning ($p=.31$). Whereas the predictive relationships among computer use to explore mathematics principles and concepts and look up ideas and information, and students' mathematics reasoning were negative, the processing and analyzing data and to practice skills and procedures were positive. None of these relationships were significant in Chinese Taipei.

Table 5: Relationships between Students' Teachers' Computer Use and Students' Reasoning.

Variables	Singapore	Chinese Taipei	Finland
Intercept	603.76*** (4.84)	601.22*** (13.88)	500.99*** (5.17)
Level 1			
Background variables			
Gender (female)	-10.96* (3.68)	-3.39 (3.76)	-3.94 (3.04)
Number of books in the home	1.10 (1.25)	17.68*** (1.51)	14.26*** (1.25)
Mothers level of education	-0.44 (0.65)	0.73 (0.93)	0.26 (1.01)
Level 2			
Students' Teachers' computer use			
Basis for instruction	29.11 (23.63)		-29.41 (31.75)
Supplement	-1.08 (19.43)	3.30 (15.60)	-2.79 (8.25)
Comfortable and Supportive environment	-1.34 (3.02)	1.17 (3.74)	0.70 (1.85)
Explore mathematics principles and concepts	21.85 (14.99)	-24.29 (18.08)	4.28 (12.87)
Practice skills and procedures	5.85 (14.51)	9.91 (30.65)	-29.18* (9.78)
Look up ideas and information	18.35 (14.83)	-11.53 (27.02)	-14.31 (10.72)
Process and analyze data	-46.54* (15.70)	24.47 (48.80)	34.51* (11.26)
Variance Components			
Level-2 between group $SD(u0)$	79.74	48.72	39.69
Level-1 within group $SD(r)$	50.39	88.93	64.81
Level 1 (n)	5927	5042	4266
Level 2(n)	330	152	258

* $p < .05$, ** $p < .01$, *** $p < .001$

Finland. Computer use by teachers as a supplement for instruction and a basis for instruction were negatively related to students' mathematics reasoning ($p = .34$ and $p = .93$). The students' teachers comfort and support available for computer use in mathematics instruction were positively related to students' mathematics reasoning ($p = .38$). Whereas there was a

negative significant relationship between teachers' computer use related to engaging students in practicing skills and procedures and students' mathematics reasoning ($\beta_{\text{Finland}} = -29.18$, $p < 0.05$), the relationship between teachers computer use that related to engaging students with activities including processing and analyzing data, and students' mathematics reasoning was positive ($\beta_{\text{Finland}} = 34.51$, $p < 0.05$). Although the relationship between teachers computer use to engage students to look up ideas and information was negative, it was not significant.

In sum, the multilevel analyses indicate that in all three countries, the variation of students' mathematics reasoning was above 35% among the students' teachers. Further, the variation in the students' mathematics reasoning was significantly predicted by activities related to having students use computers to (i) process and analyze data in Singapore and Finland, and (ii) practice skills and procedures in Finland. Other factors related to the teachers computer use have varying patterns of relationships but were not significant.

Discussion

Using the TIMSS 2011 data, the purpose of this study was to explore the influence of technology use in the teaching and learning of mathematics on eighth-grade students' reasoning skills. The findings suggest there are differences in computer usage by students and their teachers in the three countries. In this section we first discuss students' computer use in all three countries in relation to previous findings on students' computer use. We then focus on the students' teachers' computer usage, their support and comfort levels in relation to each country's policies and previous studies on teachers' computer use. Third, we give an account of the significant findings and analyze them based on previous studies and each of the countries policies.

Students' Computer Use. The students' computer use in the three high achieving nations showed differences in frequencies across countries and places. Of the three countries, Finland had the highest number of students who used computers at home and other places, and the lowest percentage of students who reported using computers at school. The Finnish school systems have made attempts at increasing students' computer usage in schools by launching ICT in schools (Niemi, et al., 2014). OECD (2015) also reported the differences in the frequency of students' computer use at home and in school.

In Chinese Taipei students' computer use at school was the highest among the three countries. One of the primary goals of the Taiwanese Ministry of Education promotes the use of technology in education (Young & Ku, 2008). Relatedly, some mathematics topics such as geometry are taught using technology (Mullis et al., 2012). Some of the software for teaching geometry include geogebra, geometers' sketchpad, etc, most of which are accessed through computers or related tools. Therefore, the technology policy in education is related to the higher frequency of students' computer use in school as shown in the findings from this study.

Over the years (1997-2013), the Singaporean education system has been involved in major initiatives to improve ICT integration in the education system (IDAS, 2008). These initiatives in education focus on ways of enriching students' learning experiences and emphasize technology use for learning. From the findings in this study, students use computers frequently at home and in school, but not as frequently in other places. The frequent students' computer usage at home and school could be attributed to the major initiatives introduced in the Singaporean education system.

In sum, students' computer use in all three countries has been a focal area of concentration for the improvement and enrichment of students' learning. However, the results show that the frequency in students computer use differs across the three countries. In fact, of

the three countries, the results of the study show that more students' use computers in school occasionally.

Teachers' Computer Use and Perceived Support & Comfortability. The teachers in Singapore had the most comfort in computer use and support for technology use in teaching. Similarly, the results indicate that the Singaporean teachers used computers most in their instruction on various mathematics activities. The initiatives related to ICT integration (IDAS, 2008) may have led to increased support in using computers among the teachers and consequently improved their levels of comfort.

The education policies in Finland suggest that teachers should incorporate basic technology in the teaching and learning of mathematics as a way of increasing student motivation (Mullis et al., 2012). Finnish teachers are encouraged to use technology in classrooms. There are, however, no specific policies about integrating technological tools such as calculators and computers to teach mathematics in Chinese Taipei; however, the use of technology for teaching and learning is one of the primary goals promoted by the Ministry of Education (Young & Ku, 2008). The fact that the policies on computer integration are less emphasized in the Finnish and Taiwanese educational policies could explain the lack of support and comfort in computer use reported by the teachers.

Does Computer Use Matter? The frequency of students' computer use at designated places, and their teachers' use of computer in instructional activities in mathematics predict students' mathematics reasoning. In Chinese Taipei, the use of computers in classroom instruction at schools was positively related to students' mathematics reasoning, whereas using computers at home and other places had a negative influence on student learning. In Singapore and Finland, computer use in other places was negatively related to students' mathematics reasoning. Previous studies point that computer use in school is related to an increase in students' achievement (Barrow et al., 2009; Eyyam & Yaratan, 2014). On the other hand, the negative relationships across the three countries confirm that the computer activities that students participate in at other places other than school do not building on their reasoning skills. These finding from all the three countries selected in this study are consistent with previous findings (e.g., Petko et al., 2016). Therefore, in other places students may be engaged in gaming, social sites, communication, which may lead to the development of habits that hinder the development of reasoning skills.

The findings also identified essential ways of integrating computer technology into mathematics instruction that might influence students' mathematical reasoning. For example, the results for Finland indicated that having students use computer technology for higher order thinking skills such as processing and analyzing data had a significant and positive relationship with students' reasoning skills as compared with simply using computer technology to help students practice mathematical concepts. These findings are consistent with the previous research concluding that student engagement in similar activities caused a gain in students learning of a particular content (Sethy, 2012). Sethy (2012) argued that computer technology resources support the development of higher-order thinking skills especially when they are applied to reasoning, reflection, and decision-making. Conversely, students in Singapore tended to have significantly lower scores when they were engaged in using computer technology to process and analyze data.

Significance and Implications of the Study

This study highlights the relationships between the extent to which computers are used for learning mathematics and students' mathematics reasoning across different contexts. The fact that in all the three countries computer use in other places was negatively related to

students' reasoning implies that spending extended time on computers out of school hinders the development of problem solving skills. In addition, the frequency of particular activities influences learning outcomes that students need for problem solving in today's technologically advanced society. For instance, in Finland, engaging students to practice skills and procedures had a negative influence on the development of students' mathematics reasoning, whereas using computers to process and analyze data was beneficial in the development of this competency. However, in Singapore, computer use to process and analyze data did not seem to promote this problem solving skill. These findings indicate that perhaps the instructional processes that include computer use differ across nations and can influence students' development of higher order thinking in divergent ways. In sum, the education policymakers and education researchers can gauge the extent of computer integration in teaching mathematics in the current information age and use the information to either adjust their policies and adapt or develop strategies and support for computer technology for mathematics instruction.

This study provides a road map on where and what to further study on the positive relationships between computer usage and higher order student thinking in mathematics, using smaller case study analysis within the selected countries. The findings from this study provide directions for future studies. For example, further studies that focus on the consistencies and divergences on computer technology in instructional practices and learning of higher order skills in mathematics would build on the finding from this study. Further, the computer programs that were beneficial for the development for this higher order thinking in Finland should be further investigated. Because educational policies related to ICT differ across contexts, such studies might reveal other important implications of computer technology use in teaching and learning mathematics that were not found in the countries selected in this study

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