ICT IN MATHEMATICS ACHIEVEMENT: EVIDENCE FROM ETIMSS 2019

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This study contributes to a growing body of research on the integration of ICT in mathematics education. The purpose of the study was the examination of the effect of ICT on student achievement in mathematics. Specifically, our aim was to investigate the effects of self-efficacy, access to ICT and opportunities to work on problem-solving tasks on mathematical achievement. We used the eTIMSS 2019 for secondary analysis and interpretation of the data concerning the students who participated in problem-solving and inquiry tasks in a computer-based assessment. The results of this study add more information to the literature about the contribution of ICT to problem-based learning in mathematics.

Keywords: ICT, mathematics achievement, eTIMSS, problem-solving, self-efficacy

INTRODUCTION

Research on the impact of Information and Communication Technologies (ICT) on learning outcomes focuses both on the effectiveness of ICT use compared to traditional teaching methods, and on the relationship between ICT use and student achievement, using large-scale survey data (Skryabin, Zhang, Liu, & Zhang, 2015). The use of ICT promotes exploratory learning, focused on problem-based learning (Oblinger, 2004) and is positively related to student achievement and attitudes (e.g., Kimmons, Liu, Kang, & Santana, 2012; Liu, Liu, Pan, Zou, & Li, 2019). TIMSS (Trends in Mathematics and Science Study) provides an opportunity to investigate the use of ICT and develop conceptual models for its use in education, considering student ability, attitudes towards mathematics, and other factors (Knezek & Christensen, 2008). The recent computer-based assessment of eTIMSS in mathematics allows the investigation of the use of ICT in mathematical problem-solving. In the context of TIMSS, many studies have found that ICT has a significant impact on student learning (e.g., Jung & Li, 2021; Namome & Moodley, 2021). The recent computer-based assessment of eTIMSS in mathematics allows the use of ICT in solving mathematical problems to be explored. However, there is a need for further research into the contribution of ICT to mathematics education, focusing on problem-solving. The aim of this study is to investigate the effects of access to ICT in math lessons, self-efficacy for ICT use, and the opportunity for problem-solving in mathematics on mathematics achievement. We used the data from eTIMSS 2019 to achieve the purpose of the study.

THEORETICAL FRAMEWORK

The theoretical overview of the present research is organised in two parts. First, the research on the contribution of ICT to teaching and learning is reviewed, while in the second part, the theoretical review focuses on research carried out in the context of TIMSS. Finally, the research gaps that this study seeks to cover are identified, and the purpose and research questions are presented.

ICT in education

Student access to a computer at school has a positive impact on student performance in reading and mathematics (Carrasco & Torrecilla, 2012). Additionally, it promotes exploratory learning, focuses on problem-solving (Oblinger, 2004), and benefits the learning experience, motivation, and engagement of students in learning (De Witte & Rogge, 2014). Using technology with an emphasis on problem-solving has a positive effect on student achievement (Hwang, Wu, & Chen, 2012) and self-efficacy (Brown et al., 2013). Self-efficacy relates to individuals' perceived abilities and their views of the skills they possess (Bandura, 1997). Liu et al. (2019) showed that there is a positive relationship between the engagement of students with problem-based environments in ICT and their achievement and attitudes in science. Problem-solving gives students an opportunity for independent learning and to practise cognitive and metacognitive skills (Liu et al., 2019). Merritt, Lee, Rillero, and Kinach (2017), in a review of experimental studies on the effectiveness of learning, conclude that an emphasis on problem-solving in mathematics is an effective teaching method that contributes to students' knowledge, attitudes, and conceptual development. Additionally, Brown, Lawless, and Boyer (2013) showed that an emphasis on problem-solving has a positive effect on student learning outcomes and self-efficacy.

TIMSS research

The TIMSS (Trends in International Mathematics and Science Study) is a large-scale assessment that was first conducted in 1995 and has continued every four years. TIMSS seeks to evaluate factors that contribute to shaping learning outcomes, providing data on student performance and factors likely to be related to student performance in mathematics and science for primary and secondary education. TIMSS transitioned to digital assessment in 2019. The eTIMSS participant countries also participated in the Problem Solving and Inquiry (PSI) assessment tasks (Mullis & Martin, 2017). The PSI tasks were added to math and science assignments to learn more about how interactive assessment items with a digital device could be used to collect student responses in TIMSS. The PSI tasks were combined into two separate eBooklets with other eBooklets of eTIMSS 2019 and TIMSS 2019 (paper and pencil) assignments (Mullis, Martin, Fishbein, Foy, & Moncaleano, 2021).

Namome and Moodley (2021) investigated the impact of ICT on learning outcomes in mathematics. Their findings showed that access to ICT during mathematics lessons has a positive effect on student achievement in mathematics. In the context of eTIMSS 2019, Jung and Li (2021) showed that the self-efficacy of students is an important factor for their positive learning experience in a computer-enhanced learning environment. Research gaps and questions

However, more research is needed to investigate the effects of access to ICT (Namome & Moodley, 2021) and the self-efficacy of students for ICT (Jung & Li, 2021) across different educational systems and countries to generalise their significance in learning. Furthermore, there is a lack of research examining the effects of ICT on the performance of students in a problem-based environment (Liu et al., 2019). Therefore, research is needed to determine the relationship between students' self-efficacy for using technology and the opportunity they are given to use ICT in mathematics teaching and learning, focusing on problem-solving in mathematics teaching and learning.

To address these gaps, the present study seeks to investigate the self-efficacy for ICT use of 4th grade primary school students, the students' engagement with mathematical problems, and the access to ICT in the teaching and learning of mathematics. The research question is: "*Are there differences in 4th graders' mathematical achievement who participated in eTIMSS regarding (a) the opportunity for problem-solving in mathematics, (b) self-efficacy for ICT use, and (c) the access to ICT for mathematical lessons?"*

METHOD

Data source

The data source for this study comes from eTIMSS 2019. The participants of the study were students from all participant countries who completed the two assessment booklets with PSI tasks. After excluding missing data, the final sample contained 30 countries and 20,161 students (Mullis & Martin, 2017).

The dependent variable is the overall score of each student in mathematical tasks. In TIMSS, five plausible values are used to represent the mathematical achievement of students due to the large number of mathematical tasks and the requirement that each student complete a booklet containing all of the tasks (Foy et al., 2017). Item Response Theory (IRT) and a regression-based approach that makes use of the context data to derive a prior distribution of proficiency are used to formulate the data in this way (Martin, von Davier, Mullis, 2020). The mean score of the five plausible values used for the overall mathematical achievement of students in this study (Marchant, 2015).

The independent variables refer to the frequency that students work on mathematical problems on their own during math lessons, their access to ICT during math lessons (regarding their teachers' responses), and their self-efficacy for computer use. Table 1 shows the measures for the three independent variables. Specifically, the first question was used as an opportunity to solve mathematical problems and was taken from the student questionnaire. With reference to access to ICT, the second question was used, regarding access to computers or tablets during mathematical lessons, and was taken from the teacher questionnaire. Finally, regarding students' self-efficacy for ICT use, seven questions from the student questionnaire were used to assess students' familiarity with performing various tasks on the computer, as detailed in the third question.

Question(s)	Measure
1. In mathematics lessons, how often do you work problems on your own?	(a) every or almost every lesson (b) about half the lessons (c) some lessons (d) never
2. Do the students in this class have computers (including tablets) available to use during their mathematics lessons?	(a) yes (b) no
3. How much do you agree with these statements? a) I am good at using a computer b) I am good at typing c) I can use a touchscreen on a computer, tablet, or smartphone d) It is easy for me to find information on the Internet e) I can look up the meanings of words on the Internet f) I can write sentences and paragraphs using a computer g) I can edit text on a computer	(a) agree a lot (b) agree a little (c) disagree a little (d) disagree a lot
Self-efficacy for computer use (Questions 3a-3g)	(a) high self-efficacy

	(b) medium self-efficacy
	(c) low self-efficacy

Table 1: Questions and measures for the opportunity for problem-solving in mathematics, the access to ICT, and the self-efficacy of students for computer use

Data analysis

For data analyses, both descriptive and inferential statistics were used to answer the research question. Therefore, three-way ANOVAs were run to investigate the differences in students' mathematical achievement towards the access to ICT during math lessons, the self-efficacy of students for ICT use, and the opportunity for problem-solving in mathematics.

Mathematical achievement of students served as the dependent variable, and access to ICT, self-efficacy of students for computer use, and opportunity for problem-solving in mathematics served as the three independent variables. The data were analysed using IBM SPSS Statistics (Version 27).

RESULTS

To investigate whether there were differences in student achievement according to access to ICT in teaching mathematics, their self-efficacy for using ICT (low, medium, high), and the frequency of solving mathematical problems in teaching mathematics (never, some courses, half the lessons, and always or almost always), we conducted an analysis of variance of three independent variables (three-way ANOVA). The findings revealed that the students' self-efficacy ($F_{(2, 20143)}=10.34$, $p< .001$), the opportunity for problem-solving in mathematics ($F_{(3, 20143)}=119.52$, $p< .001$) and the access to ICT in teaching ($F_{(1, 20143)}=12.19$, $p< .001$) had a statistically significant effect on mathematics achievement.

Regarding the interactions of the three independent variables, it was shown that the interaction of opportunity for problem-solving in mathematics and access to ICT in teaching mathematics was statistically significant ($F_{(3, 20143)}=3.58$, $p<.05$). Furthermore, the interaction between the opportunity for problem-solving and self-efficacy of students for using ICT was statistically significant ($F_{(6, 20143)}=3.03$, $p<.01$). The interaction between access to ICT in mathematics and the self-efficacy of students had no significant effect on mathematical achievement. Furthermore, there was no significant effect on mathematical achievement of the interaction of the three independent variables (student self-efficacy, access to ICT, and opportunity for problem-solving in mathematics).

Self-efficacy for ICT	Opportunity for mathematical problem-solving	$\bar{X}$	SD
high self-efficacy	Never	469.59	85.25
	some lessons	499.89	75.76
	about half the lessons	514.28	78.48
	every or almost every lesson	543.72	80.31
medium self-efficacy	never	459.15	91.82
	some lessons	495.81	82.56
	about half the lessons	510.73	82.82
	every or almost every lesson	534.83	87.68
low self-efficacy	never	444.56	89.08
	some lessons	497.3	85.08
	about half the lessons	510.41	96.33

	every or almost every lesson	515.76	97.53

Table 2: Means (X̄) and Standard Deviations (SD) of students according to their self-efficacy for ICT use and the opportunity for mathematical problem-solving

The means and standard deviations of groups of students according to opportunity for mathematical problem-solving and access to ICT are shown in Table 2, while groups of students according to opportunity for mathematical problem-solving and self-efficacy for using ICT are shown in Table 3.

ICT availability during math lesson	Opportunity for mathematical problem-solving	X̄	SD
yes	never	465.59	92.12
	some lessons	505.62	79.95
	about half lessons	518.03	79.39
	every or almost every lesson	542.50	82.03
no	never	455.96	85.79
	some lessons	490.08	79.44
	about half lessons	507.15	82.74
	every or almost every lesson	536.50	85.72

Table 2: Means (X̄) and Standard Deviations (SD) of students according to access to ICT during math lessons and the opportunity for mathematical problem-solving

Regarding the interaction of opportunity for mathematical problem-solving and students' self-efficacy in ICT, subsequent testing of differences using the Tukey test showed, as shown in Figure 2, that individual groups differ in terms of their performance in mathematics (e.g., students with

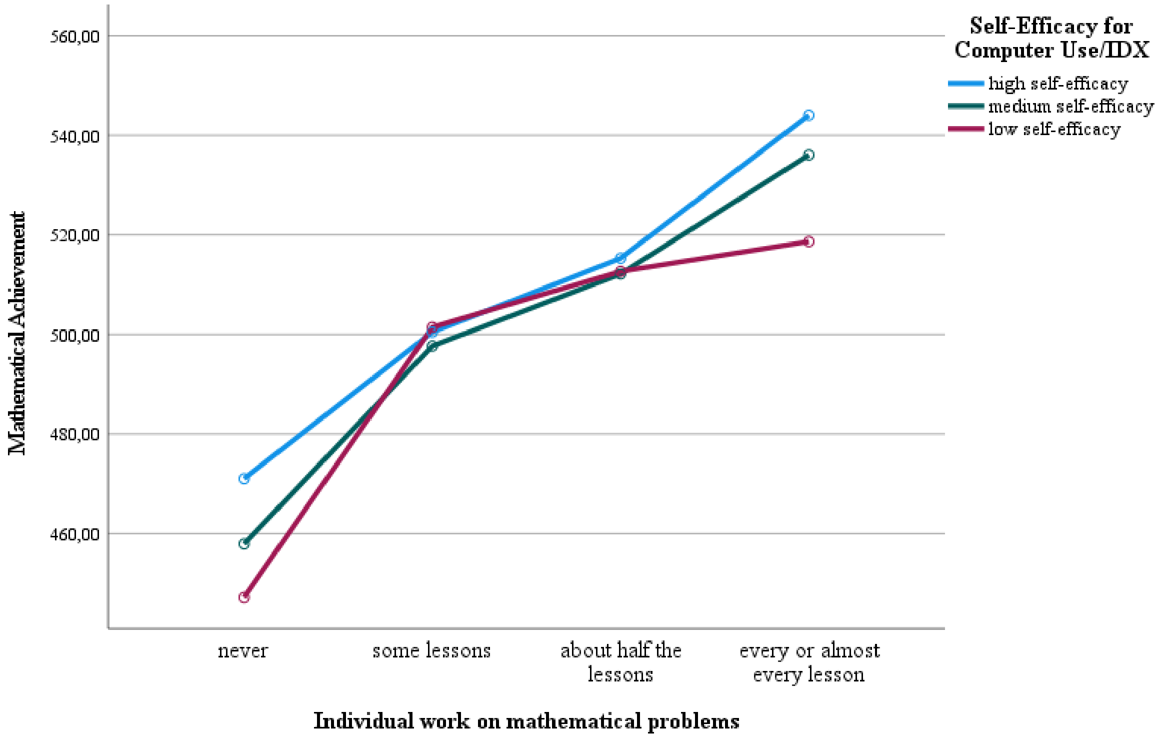

Figure 1: The interaction of opportunity for mathematical problem-solving and self-efficacy for ICT on mathematical achievement

high self-efficacy for ICT but do not solve mathematical problems compared with students with moderate self-efficacy for ICT use and solve mathematical problems in some subjects, and so on). The results showed that students who work on problem-solving in mathematics have better results according to their self-efficacy for using ICT. Students with higher self-efficacy for ICT use who solve mathematical problems in at least half of the mathematics lessons outperform students with moderate or low self-efficacy for ICT use who solve mathematical problems in some or no lessons at all.

Regarding the interaction of opportunity for mathematical problem-solving and students' self-efficacy in ICT, the Tukey difference test showed that there are differences in their mathematics performance in individual groups of students (e.g., students who have access to ICT in the mathematics course but never solve math problems compared with students who have access to ICT but solve math problems in some math lessons, and so on). The results of this interaction are shown in Figure 2. The findings revealed that students who have access to ICT in the mathematics lesson outperform students who do not have access to ICT when they solve mathematical problems. Students who have access to a computer or tablet during math lessons and work on mathematical problems on their own at least half of the time outperform students who do not have access to a computer or tablet during math lessons and have not worked on or have worked on mathematical problems by themselves some of the time.

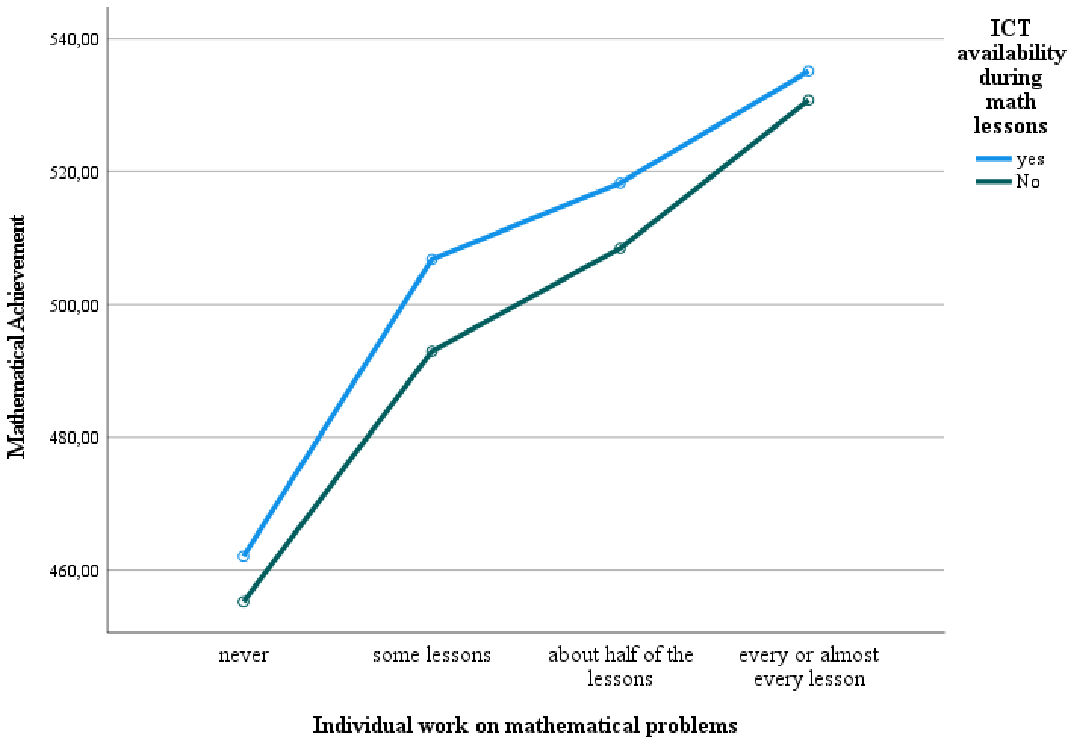

Figure 1: The interaction of opportunity for mathematical problem-solving and access to ICT during math lessons

DISCUSSION

The purpose of this study was to explore the effect of ICT factors and opportunity for mathematical problem-solving on the mathematical achievement of students. The evidence suggests that ICT has an impact on the mathematical achievement of students in a problem-solving context in math lessons. The important contribution of the study is that it adds more information to the literature on how factors related to ICT affect the achievement of students when opportunities to solve mathematical problems are provided.

The findings confirm that access to ICT and self-efficacy for ICT have a significant effect on student outcomes (Carrasco & Torrecilla, 2012; Jung and Li, 2021; Namome & Moodley, 2021). Furthermore, the results also confirm that the effect of problem-solving tasks is significant for student achievement (Merritt, Lee, Rillero, & Kinach, 2017).

Our findings provide important evidence of the interactions between ICT factors and the opportunity for problem-solving in mathematics. According to previous studies (Hwang, Wu, and Chen, 2012), access to or lack of access to ICT in the teaching of students, depending on how frequently they work on solving mathematical problems, appears to contribute positively to their mathematical performance. This result emphasises the need to use ICT in teaching, where students have the opportunity to work problem-solving tasks in mathematics.

In addition, the results revealed that students' self-efficacy to use ICT was low, moderate, or high depending on the frequency with which they solved mathematical problems. This finding is in agreement with Liu et al. (2019) and points out the need to develop and cultivate the self-efficacy of students for ICT use and, at the same time, provife them more opportunities for problem-solving in mathematics.

Finally, the findings of the research emphasise that the use of ICT has a positive effect on the performance of students in the classroom, with an emphasis on mathematical problem-solving. They emphasise the importance of students developing self-efficacy for ICT and having access to ICT during math lessons so that students can work on mathematical problems. The emphasis on creating these conditions maximises the learning outcomes of students in mathematics in a computer-based context. A limitation of this study is that the use of secondary analyses of the TIMSS, although it gives the opportunity to study multiple factors in a wide range of students from several countries at the same time, does not provide more information about the type and context of ICT use in the mathematics lesson. Future studies can shed more light on investigating the effects of ICT together with other student factors, such as students' attitudes towards mathematics, on learning outcomes and developing a framework within which mathematics learning is promoted.

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