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Mathematics Teachers' Use of Information and Communication Technologies: An International Comparison

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Abstract

There is an urgent need to understand how often teachers use information and communication technologies (ICT) in mathematics instruction. This information can provide vital links that can help stakeholders make connections about ICT use in mathematics instruction and student learning experiences with ICT. Scholars in the field have reported on the numerous challenges in schools facing ICT integration beyond availability of ICT. Understanding the frequency of ICT use can also shed light on areas that need continued research, such as examining the trends of ICT use in mathematics instruction among teachers and across countries. Additionally, in an effort to understand how teachers use ICT, there is a need to investigate the various factors that may impact ICT use in content areas such as mathematics. This study offers an international perspective that focuses on eight countries using the TALIS 2013 dataset to investigate frequency of ICT use, and examine factors that may have contributed to teachers' ICT use in mathematics instruction. This analysis shows limited ICT use in mathematics instruction and differences in ICT use among the countries. Teacher cooperation, mathematics self-efficacy, and professional development in ICT skills were significant predictors of ICT use. Implications for research and policy are discussed.

Introduction

In the 21st century, information and communication technologies (ICT) have become ubiquitous and integral in daily living. ICT refer to electronic devices (e.g., laptops, chrome books), handheld devices (e.g., iPads®, iPods), interactive devices (e.g., interactive white boards), application software, and social media tools. They are used for commerce, communication, information gathering, learning, and a myriad of other purposes. Although many K-12 schools in the United States have computers in the classrooms, some have argued little has changed in terms of teaching practices or student outcomes (Cuban, 2001, 2013). It is often assumed that the mere presence of technology in the classroom will lead to changes in instructional practices and enhance student learning.

Other scholars have continued to search for reasons that seem to contribute to ICT less than transformative edge in teaching and learning. Zhao, Pugh, Sheldon, and Byers (2002) posited that most professional development for teachers tends to focus on the technical aspects of the technology and neglects the social and organizational aspects of technology integration. The authors argued that teachers with an understanding of the social and organizational culture in a school are more likely to negotiate some of the barriers that get in the way of technology integration such as existing school patterns towards technology use. These teachers may negotiate the barriers through collaborating with multiple parties in the school either to have access to technology resources or to garner peer support. The organizational culture refers to the available administrative support that allows technology integration, such as the availability of technical assistance and willingness of school leaders to take risks that may lead to innovative changes in teaching and learning. In a school environment or an education system, various stakeholders (e.g., teachers, policy makers, parents) may have different assumptions, perspectives, and attitudes towards using technology, student learning, or the role of the teacher in a technology-rich environment. Therefore the development of an organizational culture that explores the differences and assumptions among the stakeholders and further develops a supportive environment cannot be underestimated.

Examining the different relationships between key stakeholders (e.g., teachers, students, school leaders) in a learning environment can provide insights into technology integration. Additionally, these relationships can explain the factors that contribute to the varied ways that teachers use technology in instruction, and help explain the persistent puzzle of limited ICT use (Cuban, 2013). Somekh (2007) highlighted the importance of understanding innovation from a socio-cultural perspective as this allows stakeholders to examine the different relationships that exist in a learning environment. For instance, there is a need for careful consideration of curriculum, pedagogy, professional development, teacher beliefs, teacher training, school leadership (Ertmer & Leftwich, 2010; Frank et al., 2011; Hughes, 2005) and more importantly, the development of a shared meaning among multiple stakeholders (Fullan, 2016). In the context of ICT integration, Fullan elaborated on the need to build capacity and collaborative cultures in schools. Building capacity involves building skills and experiences that foster the development of new experiences and increase motivation for teachers to engage in change processes. Building capacity includes providing professional development for teachers, and engaging in discussions on ways to effectively and efficiently use available ICT resources. These social and organizational aspects impact ICT integration. Furthermore, it is imperative for stakeholders to critically examine current perspectives in schools regarding ICT integration to ensure that students' educational interests transcend possible agendas such as profit making from enterprises with vested interests. Schools are then faced with the need to critically examine the motives that underpin ICT integration (Sewlyn, 2012). Sewlyn challenged the underestimation of conflicting business interests (e.g., profit motives) versus education interests (e.g., democratic values of education) that can potentially widen the digital divide and increase inequalities in society.

Therefore, it is imperative that teachers, administrators and policymakers understand how ICT are actually used and how often they are used in the classroom to develop a nuanced understanding of the relationship between teachers' ICT use, teacher beliefs, and teacher training, instead of making assumptions that the mere ICT presence in the classroom leads to effective ICT use in teaching and learning. This information can inform instructional practices and promote effective ICT use that enhances instead of hinders student learning. Furthermore, available literature addresses ICT use and student achievement with little attention to teachers' ICT use across content areas. Although examining student ICT use is critical, developing an understanding about how often ICT is used in mathematics instruction can inform researchers, teacher trainers, policy makers on the existing gaps between ICT use in instruction and the impact of ICT use on students' learning. ICT can be used in mathematics instruction to promote students' understanding of mathematical skills and concepts, make conjectures and develop high order skills. Understanding how often teachers use ICT in content areas such as mathematics instruction can provide a clearer picture on aspects and affordances from technology that improve teachers' ICT use in mathematics instruction. Frequency of ICT use can also shed light on areas that need continued research, such as examining the variation of ICT use among teachers in mathematics instruction across classrooms or countries.

This paper adds to the literature on ICT use and specifically seeks to fill the gap on understanding teachers' ICT use in mathematic by providing an international perspective that focuses on teachers' use of ICT in mathematics instruction in eight countries. Additionally, the analyses illuminate possible factors that contribute to ICT use across the eight countries.

Background

ICT Use

Following the increased proliferation of technologies in schools, research shows a mismatch between technology availability, access, frequency of technology use and the quality of instruction using ICT. Successful integration of ICT in schools will depend on the deeply held beliefs and cultures of practice within schools that may lead to systematic ICT integration in instruction (Bain & Weston, 2009). In the theory on diffusion of innovations, Rogers (1983) argued that the social structure of an individual adopting an innovation impacts the integration of the innovation. For instance, in a study with a sample of Korean teachers, Baek, Jung, and Kim (2008) found the strongest factor that influenced technology use in the classrooms was merely the compliance to external requests and expectations from external parties (e.g., requirements from the Ministry of Education, common perceptions that good teachers use technology well). Researchers have explored the factors and barriers that hinder ICT use in classrooms that already have access to ICT. Additionally, scholars (Burns, 2013; Overbay, Patterson, Vasu, & Grable, 2010; Warschauer, Zheng, Niiya, Cotton, & Farkas, 2014) have tackled some of the micro and macro factors that influence technology integration, such as cultures of practice, educational policies on ICT, school organization and ICT infrastructure.

Cultures of practice include beliefs about teaching, learning, and the ways that knowledge is constructed and disseminated to students. Researchers, Schussler, Poole, Whitlock, and Evertson (2007) noted that the minimal use and lackluster results from technology use may signify a complex situation in and around the learning environment. Currently, even for classrooms that have integrated ICT, changes from old practices to new practices revolve around automation instead of embedding technology and creating richer teaching and learning experiences where students learn with technology (Cuban, 2013). Following the continued investment in technology, there is a need to evaluate current pedagogical approaches and investigate pedagogies that are effective when integrating ICT, by exploring pedagogical innovations that ultimately lead to increased student achievement. Choy (2013) argued that changing the mindset and perceptions of teachers is equally as important as examining the technology; this premise accentuates the need to address the role of technology on beliefs and attitudes in teaching (Mueller, Wood, Willoughby, Ross, & Specht, 2008). However, even before making that leap that helps us understand the pedagogical approaches, we need to understand the frequency of ICT use in instruction for subjects such as mathematics, and the factors that promote or hinder ICT use. Researchers have reported that teachers use ICT more in English instruction compared to mathematics. For instance, in Singapore, Tay, Lim, Lim, and Koh (2012) reported that teachers incorporated ICT differently and more frequently in English classes than in mathematics. In mathematics, ICT was for skills practice compared to English classes where students used ICT in knowledge construction.

Previous Studies

Previous studies used nationally representative data such as the Programme for International Student Assessment (PISA) and examined the impact of the quality and quantity of ICT use on students' scores (Biagi & Loi, 2013; Cheema & Zhang, 2013; Güzeller, 2014). Ottstead (2010) provided country-specific information on patterns of pedagogical ICT use for Finland, Denmark and Norway that continued to reveal discrepancies between actual ICT use in the classroom and investments in ICT that are often accompanied by the inclusion of ICT related goals in policy documents. Although Finnish teachers demonstrated autonomy in decision-making, they expressed that lack of training in implementing the ICT in instruction limited ICT use, whereas Norwegian teachers upon implementing ICT in the curriculum started to show increase in ICT use (Ottstead, 2010).

Scholars (e.g., Fullan, 2016) have reported that school climate can impact ICT integration, implementation, use and management. In a nutshell, teachers do not teach in a vacuum but their instructional practices are nested in a socio-cultural context with micro and macro factors. Micro factors are within the classroom, including students, the classroom environment and available resources. Macro factors exist outside the classroom environment and include administrators, teachers, and the community. Therefore, teaching and learning in the classroom takes place in a larger context influenced by the school climate. Consequently, innovations such as ICT integration must take a socio-cultural perspective that takes into account characteristics that influence human behavior in those contexts (Somekh, 2007). Socio-cultural perspectives examine social and organizational factors that can impact ICT integration. Moreover, certain factors such as teaching approaches contribute to ICT use. Scholars, Li and Ma (2010) reported that technology had stronger effects on student achievement where teachers used a constructivist approach (defined as a teaching philosophy that encourages a more student focused environment and less of a teacher-centered environment) compared to the traditional approach of teaching that is more teacher-driven.

Taken together, different social, and organizational factors are interconnected and influence decisions on how resources are procured, integrated and become part of the school culture. Fullan (2016) emphasized the need for "connected autonomy" (p. 262), where people collaborate within the school, with other schools, while linking to overarching educational policy priorities. These connections and collaborations can lead to sharing and borrowing of ideas on ICT use, effective pedagogies, or the sharing of expertise, and development of shared meaning that may lead to transformative teaching and learning using ICT even across countries in critical subjects such as mathematics.

By the same token, to glean the international trends on ICT use in mathematics instruction and to add to the literature base, this paper accomplishes three objectives. First, this paper examines the extent to which mathematics teachers use ICT across the countries in the analytic sample. Second, the analysis in this paper investigates whether mathematics teachers have different levels of professional development needs in ICT compared to non-mathematics teachers. Third, the analysis explores factors that predict ICT use in mathematics instruction for teachers in the sample. This analysis provides insightful information on the usage of ICT in mathematics instruction. To accomplish these objectives, I used the Organization for Economic Co-operation and Development (OECD) Teaching and Learning International Survey, TALIS (2013) dataset.

Research Questions

To understand the extent to which mathematics teachers use ICT across the sampled countries, to examine differences in professional development needs between mathematics and non-mathematics teachers, and to examine the factors that predicted ICT use, I developed three research questions and hypothesized the following:

1. To what extent do mathematics teachers use ICT?

   I hypothesized that teachers in the sampled countries had limited ICT use in mathematics instruction and the frequency of ICT use varied among the countries.

2. Do mathematics teachers have different levels of professional development needs compared to non-mathematics teachers in ICT?

   I hypothesized that mathematics teachers had the same professional development needs in ICT as non-mathematics teachers.

3. What factors predict ICT use among mathematics teachers?

   I hypothesized that constructivist beliefs were a strong predictor of ICT use. Teachers with constructivist beliefs used more ICT in mathematics instruction. Also, teachers' mathematics self-efficacy and level of preparedness in content, pedagogy and classroom practice can impact teachers' use of ICT. Lastly, I hypothesized that school climate (e.g., teacher cooperation, a collaborative culture and presence of administrator support) was a strong predictor of ICT use.

Method

Data Source and Measures

Data: The Teaching and Learning International Survey (TALIS, 2013) is one of the largest international surveys with a main focus on the learning and teaching environment. The survey drew school and teacher level data from 33 countries (24 OECD countries & 9 partner countries). The data was collected from 10,000 schools and more than 170,000 teachers. The international sampling plan was a stratified two-stage probability sampling design. Teachers were randomly selected from randomly selected schools. Data collection included surveys with (a) teachers from lower secondary schools and an opportunity for participation was offered to primary and upper secondary school and (b) surveys from principals.

TALIS was conducted to collect data that would provide directions in policy development. Some of the policy areas included type of feedback that teachers received and the outcomes of this feedback on teaching practices. In addition, the feedback provided information on the amount and type of professional development, impact of professional development, obstacles to opportunities for professional development, ways that school level policies and practices influenced the teachers' working conditions, and degree to which current trends in school leadership impacted teachers' learning and working conditions.

The analytic sample in this study consists of 6,570 teachers from eight countries: Australia, Finland, Latvia, Mexico, Portugal, Romania, Singapore, and Spain. These teachers from sampled countries participated in the 2012 PISA and completed the additional mathematics questionnaire. The TALIS-PISA link provided information on teaching practices at the classroom level. The sample demographics of teachers are shown in Table 1. It is important to note that the TALIS (2013) technical report states that the TALIS results will not be used to interpret the students' scores on the PISA but the results should instead be used to understand teacher/principals responses (OECD, 2013). As an example, for this analysis the focus is on the teachers' frequency of ICT use in their mathematics instruction as well as an investigation of possible predictors for the ICT use across the different countries.

Measures: In this section I provide the outcome variable and the independent variables that I used in the analyses. Table 2 outlines each of the variables used in the analysis, their description and sample items.

Outcome variable: ICTUSESUM

This outcome variable is the sum of the number of ICT teachers used in mathematics instruction. After examining the distribution showing ICT use, the distribution was skewed showing that most of the teachers did not use ICT. Therefore, I recoded the variables that asked how frequently ICT software was used in teaching for drill and practice, topic specific activities, data analysis, assessing student progress, and ICT for Internet projects. The original response scale range was from 1- 4, *1- never or almost never, 2- occasionally, 3 - frequently or 4 - always or almost always.* The recoded variable was *0 - never or almost never and occasionally, 1 – frequently and always or almost always.*

Table 1. Mathematics teachers: Sample demographics

Variable	%
Gender	
Female	49.0
Male	51.0
Countries	
Australia	13.0
Finland	3.0
Latvia	1.0
Mexico	48.0
Portugal	4.5
Singapore	1.7
Spain	21.0
Romania	6.5
Age	
20-35	24.0
36-51	54.0
52-67	21.0
68+	0.3
Employment Status	
Full time (> 90% of FT hours)	67.0
Part-time (71-90% of FT hours)	12.0
Part-time (50-70% of FT hours)	11.0
Part-time (less than 50% of FT hours)	9.0
Teaching Experience	
0-15	52.3
16-31	39.7
32-48	8.0
49-50	0.1
Education	
Post-secondary	4.0
Tertiary	1.3
Bachelors	92.0
Masters	3.1
Teacher Training	
Yes	69.0
No	31.0
Students with Special Needs	
None	40.0
Some	58.0
Most	1.0
All	0.3

Note: N = 6570; FT = full time

Then I calculated the sum from the five questions covering the frequency of ICT use in the different categories (drill and practice software, topic specific software, data analysis software, assessing student progress, and ICT for Internet projects). The new variable is a sum of the total number of ICT teachers used in instruction and student assessment. The minimum and maximum of the new variable (ICTUSESUM) is 0 and 5 respectively.

Independent Variables

Key Predictor Variable

Constructivist beliefs are characterized by a teachers' ability to prioritize thinking and reasoning processes as well as to promote a students' inquiry and problem-solving skills. This is the main predictor for this analysis. It is a composite variable with a Cronbach's reliability of 0.7 as provided in TALIS technical report (OECD, 2013). The 4 items with the response range from 1-4, *1- Strongly disagree, 2- Disagree, 3 –Agree, 4 - Strongly agree.*

Table 2. Variables Investigated and sample items

Variable	Domain	Description	Sample Item
Constructivist beliefs α =0.7	Teaching	4 items with the response range from 1-4, *1- Strongly disagree, 2- Disagree, 3 – Agree, 4 - Strongly agree*	My role as a teacher is to facilitate students' own inquiry; Students learn best by finding solutions to problems on their own; Thinking and reasoning processes are more important than specific curriculum
Mathematics self-efficacy α=0.7	Teaching	6 items with the response range from 1-4, *1- Strongly disagree, 2- Disagree, 3 – Agree, 4 - Strongly agree*	I am able to ask questions that get students to think deeply about mathematics; I have a hard time getting students interested in mathematics; I am able to get my students to feel confident in mathematics
Teacher cooperation	School climate	6 items with the response range from 1-6, *1- never, 2- once a year or less, 3 –2 times a year, 4 – 5-10 times a year, 5- 1-3 times a month, 6-once a week or more*	How often do you? Exchange teaching materials with colleagues; Engage in discussions about the learning development of specific students
Teacher participation in decision making	School climate	The scale ranged from 1- 4, *1- strongly disagree, 2- disagree, 3- agree, 4 – strongly agree.*	This school provides staff with opportunities to actively participate in school decisions
Collaborative culture in school	School climate	The scale ranged from 1- 4, *1- strongly disagree, 2- disagree, 3- agree, 4 – strongly agree.*	There is a collaborative school culture which is characterized by mutual support.
Teachers receive administrative support	School climate	The scale ranged from 1- 4, *1- strongly disagree, 2- disagree, 3- agree, 4 – strongly agree.*	Mathematics teachers in my school have the support of the school administration.
Teacher- related preparedness in content, pedagogy, classroom practice	Background	The response scale range was from 1- 4, *1- not at all, 2- somewhat, 3 - well or 4 – very well*	In your teaching, to what extent do you feel prepared for content, pedagogy, and classroom practice?
Professional Development needs	Teacher professional development	The response scale range was from 1- 4, *1- no need, 2- low level of need, 3 – moderate level 4 – no need*	Indicate to what degree you need professional development
Professional Development in ICT skills	Teacher professional development	The response scale was yes or no	Did the professional development activities you participated in during the last 12 months cover the following topic (ICT skills)?
ICTUSE	Students	The scale ranged from 1- 4, *1- never or almost never, 2- occasionally, 3- frequently, 4 – always or almost always*	Over the course of the school year, how frequently do you use ICT resources in teaching?

Note. ICT = information communication technology.

Table 3. Means and standard deviations of teachers

Variable	*math*		*non-math*	
	M	*SE*	*M*	*SE*
Age	43.57	0.36	42.65	0.20
Teaching Experience	16.56	0.39	16.05	0.21
Formal Education	2.95	0.01	2.93	0.01
Training Program	1.32	0.02	1.29	0.01
Training in Technology				
During Level 4 or 5B	1.77	0.02	1.83	0.01
During Level 5A or above	1.65	0.02	1.75	0.09
As a subject specialization	1.83	0.01	1.86	0.01
ICT Professional Development Need	2.49	0.04	2.59	0.02
ICT Professional Development Need	1.25	0.01	1.34	0.01
ICT Professional Development Need	3.19	0.03	3.22	0.02
Mathematics				
Content Preparedness	3.36	0.05	3.33	0.02
Pedagogy Preparedness	3.16	0.03	3.15	0.02
Classroom Practice	3.16	0.04	3.20	0.02
Self-efficacy	11.06	0.09	11.16	0.26
			13.17	0.05
Constructivist Beliefs	13.24	0.08		
School Environment				
Collaborative Culture	2.77	0.03	2.80	0.02
Administrators' Support	2.95	0.04	2.56	0.16
Teacher Cooperation	10.08	0.09	10.07	0.05
Participate in Decision Making	2.64	0.08	2.68	0.02
ICT Use (Teachers)				
Drill and Practice Software	1.73	0.03	1.79	0.13
Topic-Specific Software	1.85	0.03	1.82	0.17
Spreadsheets/Data Analysis	1.66	0.03	1.63	0.10
Assessing Student Learning	1.63	0.03	1.71	0.14
Internet Resources	2.38	0.04	2.53	0.13

Note. ICT = information communication technology.

Teacher Level Variables

As outlined in Table 2 teacher level variables examined mathematics self-efficacy, teacher cooperation, teacher preparedness, teacher participation (school climate), and professional development training in ICT skills. I selected these variables as covariates because the literature base on ICT integration has shown that organizational and social factors impact technology integration. The overall school culture towards innovation and technology use, leadership in continuous development efforts and professional development has been reported as having an influence in technology integration in teaching and learning.

(a) Teacher Mathematics Self-efficacy: This was a composite variable with a Cronbach's reliability of 0.7 as provided in the TALIS technical report (OECD, 2013). Mathematics self-efficacy was measured by asking teachers questions about their mathematics teaching in regards to asking students questions that get them to think deeply about mathematics, ease of developing students interest in mathematics and ability to get students to feel confident in mathematics.

(b) Teacher Cooperation: This variable asked teachers about their frequency of exchanging teaching materials with colleagues, and frequency of engaging in discussions about the learning development of specific students.

(c) Teacher Preparedness: This variable asked teachers to rate the extent to which they felt prepared for content, pedagogy, and classroom practice.

(d) Teacher Professional Development – Training in ICT Skills: This variable asked teachers if they participated in professional development activities covering ICT skills during the last 12 months.

(e) Teacher Participation: I identified three variables that examined school climate (a) availability of opportunities for staff to actively participate in school decisions (b) existence of a collaborative school culture which is characterized by mutual support (c) availability of administrative support.

Analytic Method

To address my first research question, to examine the descriptive statistics, I used the recoded ICTUSESUM variable. The new variable is a sum of the number of ICT teachers used ranging from 0 to 5. To answer the second question, I generated the means for professional development needs in ICT for mathematics teachers and non-mathematics teachers. To establish if the mean differences between the two groups of teachers were significant, I examined the t values for statistical significance. I used the poisson regression model to account for the skewness of the ICTUSESUM variable. To address the third question, I conducted poisson regression analyses to examine school and teacher level variables that predicted the number of ICT mathematics teachers used in instruction. To account for differences in ICT use across countries, I included country fixed effects to each model. In all descriptive analyses and regression models, I incorporated the TALIS survey sample weights to account for the complex survey design and generate population estimates. All analyses were conducted in Stata 14.0.

Results

Table 3 presents the descriptive statistics for the analytic sample of mathematics and non-mathematics teachers. The descriptive statistics include age, education background, teaching experience, teacher training, and professional needs in ICT skills. The two groups of teachers did not differ significantly on teaching experience, formal education or on teacher training. However, there were statistically significant differences between the two groups on age, t (26,568) = 2.22, $p < .05$.

Research Question 1: Trends in ICT Use

Mathematics teachers' ICT use across the sampled countries is shown in Figure 1. The range of the number of ICT used was 0 to 5. The average number of ICT teacher used was $M = 1.04$, $SE = 0.05$. Portugal had the highest mean number of ICT use, $M = 1.62$, $SE = 0.08$ while Finland had the lowest mean number of ICT use, $M = 0.27$, $SE = 0.03$. From this analysis, four countries (Finland, Romania, Singapore, and Spain) had below average ICT use in mathematics instruction based on information in the analytic sample.

Research Question 2: Levels of Professional Development Needs

On average, mathematics teachers showed lower professional needs for ICT skills compared to non-mathematics teachers. Table 4 shows the mean differences for professional development needs for ICT skills between the two groups, mathematics teachers ($M = 2.48$, $SE = 0.04$), and non-mathematics teachers ($M = 2.59$, $SE = 0.02$). The mean differences were statistically significant, t (26,128) = 2.32, $p < .05$, with mathematics teachers showing lower needs. However, the difference was small and not significant in practical terms (b = 0.11, $p < .05$).

Table 4. Summary of levels of professional development needs

Teachers	Mean	Std. Err.	[95% Conf. Interval]	
non-math	2.59	.0204	2.556	2.636
math	2.48	.0414	2.407	2.570

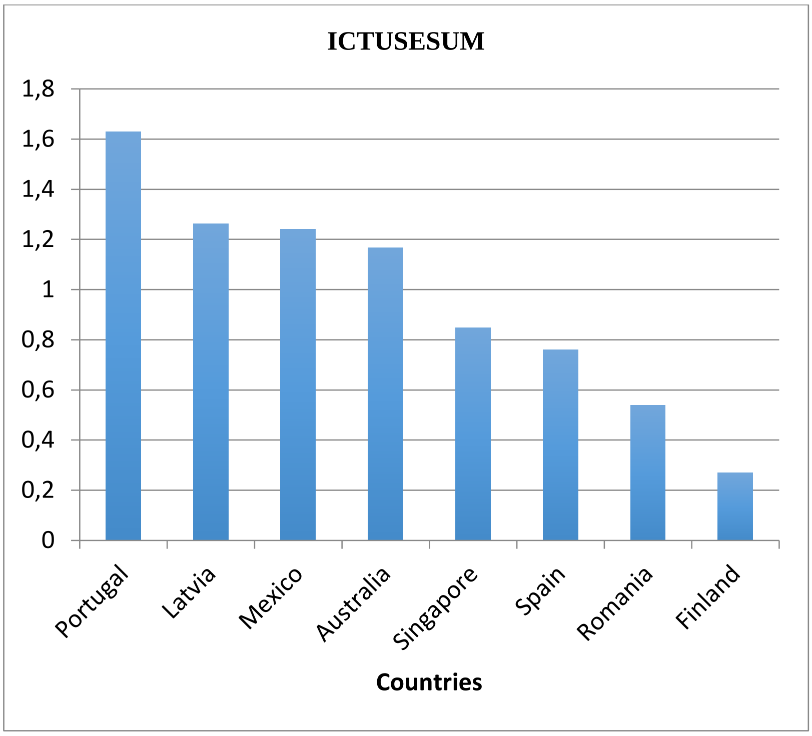

Figure 1. Means of ICT use

Research Question 3: Factors Contributing to ICT Use

In Table 5, I present results from poisson regression models showing variables that contributed to the frequency of ICT teachers used in mathematics instruction. To account for the independence assumption, each ICT use represents a teachers' ICT use in the sample. I exponentiated the coefficients from the poisson regression analyses to find the incident rate ratios as displayed in Table 5. In model 1 (column 1 of Table 5), as teachers' constructivist beliefs increased by one point, on average the rate of teachers' ICT use was likely to increase by 5.2%. In model 2 (column 2 of Table 5), after I added mathematics self-efficacy, and teacher preparedness (content, pedagogy, or classroom practice) variables, as teachers' constructivist beliefs increased by one point, on average the rate of ICT use increased to 6.1% ($p < .01$), and as mathematics self-efficacy increased by one point, on average the rate of ICT use increased by 9.3% ($p < .001$). The teacher preparedness variables did not result in any statistically significant differences in the rate of teachers' ICT use in mathematics instruction.

In model 3 (column 3 of Table 5) I added teacher cooperation and school climate variables. Here, as teachers' constructivist beliefs increased by one point, on average the rate of ICT use increased by 4.1% ($p < .05$), as teachers' mathematics self-efficacy increased by one point, on average the rate of ICT use increased by 7.8% ($p < .001$), and as teacher cooperation increased by one point, on average the rate of ICT use increased by 8.6% ($p < .01$). Constructivist beliefs, teacher cooperation, teachers' mathematics self-efficacy support showed a significant and positive direction change on teacher's use of ICT. However, the rate of teachers' ICT use decreased by 18% for teachers who received administrators' support.

In the last model, model 4 (column 4 of Table 5), I added all the variables including professional development training in ICT skills to the analysis. Accounting for mathematics self-efficacy, teacher cooperation, school climate, and professional development in ICT skills, a teacher's constructivist beliefs was not a significant predictor of the frequency of ICT a teacher used in instruction. However, mathematics self-efficacy, teacher cooperation and teacher participation in decision making, and professional development in ICT skills contributed to an increase in the rate of ICT teachers used in mathematics instruction. Similar to model 3, administrators' support contributed to a decrease in the rate of teachers' ICT use in instruction. Availability of ICT as a topic during professional development on average increased the rate of teachers' ICT use in mathematics instruction by 34% ($p < .001$) and this was statistically significant in comparison with teachers who did not receive professional development in ICT skills.

Table 5. Summary of poisson regression analyses (incident rate ratios)

	1 b (*SE*)	2 b (*SE*)	3 b (*SE*)	4 b (*SE*)
Constant	0.578 (0.168)	0.124*** (0.047)	0.195*** (0.080)	0.1556*** (0.067)
Constructivist Beliefs	1.052* (0.022)	1.061** (0.021)	1.041* (0.021)	1.030 (0.020)
Mathematics Self-Efficacy		1.093*** (0.019)	1.078*** (0.018)	1.060*** (0.019)
School Climate – Teacher Cooperation			1.086** (0.029)	1.099*** (0.027)
School Climate – Decision Making			1.198 (0.117)	1.242* (0.17)
School Climate – Collaborative Culture			1.018 (0.074)	1.000 (0.078)
School Climate - Admin Support			0.812*** (0.046)	0.812*** (0.053)
Teacher Preparedness-Content		0.923 (0.066)		0.852* (0.056)
Teacher Preparedness-Pedagogy		1.163 (0.101)		1.106 (0.096)
Teacher Preparedness-Classroom Practice		1.064 (0.081)		1.158 (0.097)
Professional Dev. – ICT Skills for Teaching				1.343*** (0.122)
Observations	5.116	5.112	5.061	4.318

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

Discussion

In my study, I hypothesized that there would be limited ICT use in mathematics instruction among countries and this was confirmed in my study. From this analysis, four countries (Portugal, Latvia, Mexico, and Australia) had above average ICT use in mathematics instruction based on information in the analytic sample. This confirms the literature that ICT remains in the periphery in instruction for critical subjects such as mathematics. Also, I hypothesized that the frequency of ICT use would vary among the countries and this was also confirmed in my study with the different mean differences in ICT use among the countries. For instance, Finland has the lowest mean compared to Portugal with the highest mean of ICT use in mathematics instruction, while Mexico and Latvia showed similar levels of ICT use. These differences in ICT use could be attributed to different policies on ICT use or differences in teachers' beliefs and attitudes towards ICT use. Further research is needed to glean into possible reasons for the variation.

Self-efficacy is a teacher's perception of their capability to successfully accomplish their responsibilities and this includes persistence (Bandura, 1977a). In my analysis, mathematics self-efficacy was a significant predictor of ICT use. It is plausible that teachers with a strong mathematics self-efficacy were willing to take risks in using ICT for mathematics instruction and transferred this risk taking to their students, allowing students to use more ICT in their learning. Also, mathematics self-efficacy was significant in explaining the number of ICT teachers used more so than teachers' preparedness in pedagogy or classroom practices. Again, this can be attributed to the risk taking and persistence element present in self-efficacy that goes beyond preparedness in content and pedagogy. Researchers have documented that teachers with teaching experience and a strong grasp of content pedagogy are more likely to use ICT in ways that provide students with opportunities to participate in high-level tasks (Hughes, 2005). In my analysis, teachers' preparedness on classroom practice or pedagogy did not show any significant differences in the number of ICT they used. However, teacher preparedness of content showed a reduction of ICT use at the rate of 15% in the full model. This was a surprising finding. It may be that teachers who felt prepared to teach the content did not feel the need to use ICT. Additionally, it may be that teachers who felt prepared to teach the content did not find *compatibility* with using ICT in mathematics instruction. C*ompatibility* as the level at which the innovation fits with an individual's current beliefs, knowledge levels, or experiences (Rogers, 1995). It is likely that, if a teacher does not view ICT as an innovation compatible with current knowledge or pedagogy, this may impact the integration of the innovation.

Constructivist beliefs remained a significant predictor in explaining the number of ICT a teacher uses in instruction when taking mathematics self-efficacy and teacher preparedness into consideration.

Teacher cooperation contributed positively to the number of ICT teachers used in mathematics instruction. This finding can be extrapolated to show that when teachers work together, they are likely to learn, and share ideas on ways to integrate, and use ICT in mathematics instruction leading to increased frequency of ICT use. Furthermore, teacher cooperation may provide teachers with support as they become more willing to take risks in using ICT in instruction. Engaging in innovative teaching practices such as integrating technology can involve an element of risk taking. This study showed administrator support reduced the likelihood of the number of ICT a teacher used in instruction. This finding can be explained by existing school policies on ICT use, leadership style or an administrators' vision for ICT in teaching and learning. If the administrator does not offer support or share a vision that promotes ICT use in teaching mathematics, then the support may not promote the use of ICT. Administrator support is critical in determining a school culture including a culture of innovation such as using ICT for instruction. Similarly, the presence of a collaborative culture did not explain significant impacts of the likelihood of the number of ICT a teacher used in mathematics instruction. This finding highlights the possibility that teachers and stakeholders at a school may not have developed a shared vision on the role of ICT in mathematics instruction. In a scenario where teachers are actively participating in decisions about ICT use in mathematics instruction, the results may be different because of the centrality placed on ICT in mathematics instruction. This school environment may be boosted by a collaborative culture that may in turn impact the number of ICT used in instruction. The availability of ICT skills as a topic for professional development contributed to the largest increase in a teacher's ICT use. Overall, this analysis provides pertinent information for future considerations of ICT use in mathematics instruction.

There are three limitations in my study. First, although the study included a large number of participants, it was done with a specific population of teachers from OECD member and partner countries. This limits the generalizability of the findings on ICT use in mathematics instruction to wider population of teachers in non-OECD and non-partner countries. Second, although the TALIS 2013 provided rich information about teachers learning and working conditions, the questions in the survey may not be neutral, and this may limit the information collected as a result of differing interpretations, or differences in the definition of words, concepts and starting points when self-reporting about the school or instructional practices. The countries in the sample may have varied policies or resources on ICT integration that impact ICT use, and these variations may not be captured in the survey questions. Similarly, the level of integration of ICT in the school or country may be different among the countries and this may impact ICT use. Third, I did not include teachers' use of ICT in research projects because this variable included mathematics and non-mathematics teachers. Projects are common in mathematics instruction and excluding this data potentially left out one more way that would have increased the number of ICT used in mathematics instruction.

Conclusion

This study sought to examine how frequently teachers used ICT in mathematics instruction in eight countries internationally. The findings showed that the teachers on average demonstrated limited ICT use in mathematics instruction with some countries such as Portugal showing the highest ICT usage. These findings allows stakeholders, including researchers, to understand whether teachers incorporate ICT in mathematics instruction before making any decisions on the effectiveness of ICT on student outcomes, and to effectively assess returns of ICT investment. Mathematics teachers showed a lower need for professional development in ICT skills compared to non-mathematics teachers. However, this difference was small in terms of practical significance. Additionally, the study investigated variables that may predict ICT use in mathematics instruction such as teacher cooperation. Teacher cooperation, teachers' mathematics self-efficacy and professional development in ICT were strong predictors of ICT use. If stakeholders care about the return on investment from ICT in schools, and largely how ICT affect students' learning, understanding ICT usage and the contributing factors that influence teachers' ICT use can allow administrators, curriculum developers and other stakeholders to target policies and professional development that promote effective and high quality ICT use.

Recommendations

Research

There is a need for continued qualitative and quantitative research on the ecological perspectives of ICT integration to uncover the different factors that promote or hinder ICT use in mathematics instruction. Researchers and practitioners may find it beneficial to collaborate in action research in an attempt to understand factors that may examine effective and strategic ICT use, particularly those factors that are not captured through questionnaires. Undoubtedly, questionnaires capture rich data that inform researchers and policy makers on teaching and learning aspects, and it is for this reason that data collection instruments should continuously be evaluated, and tested for any kinds of biases in order to get high quality information from respondents. Understandably, this charge may present a challenge when trying to strike the right balance between length and the quality of questions. However instrument developers should not compromise quality for quantity. Additionally, researchers should explore creative ways to collect data that can supplement information from questionnaires to counter not only verification challenges but also to provide a preponderance of data. This can allow deeper analysis of instructional practices. For instance, including open-ended questions can provide teachers a space to provide their voice in an elaborate manner. Lastly, research is needed that goes beyond examining the frequency of ICT use, and instead examines how teachers use ICT in mathematics instruction.

Policy

This analysis provides evidence of the role of professional development in ICT skills for mathematics teachers. Professional development in ICT skills is a significant reason that impacts teachers' effective integration of ICT in mathematics instruction. Content-specific professional development can increase the frequency of ICT use and more importantly impact the quality of ICT use in mathematics instruction. Also, stakeholders developing a shared vision for ICT in mathematics instruction, building capacities, collaborative cultures, communities of practice and providing administrator support on ICT integration can contribute positively to effective ICT use**.** Lastly**,** collaboration among policy makers and key stakeholders (e.g., teachers, curriculum developers, instructional coaches) is critical in aligning mathematics curriculum with ICT goals to provide a clearer path for teachers on the role of ICT in teaching and learning.

Notes

The authors' research interests include: understanding pedagogies that can be paired with ICT to enhance mathematics learning experiences, understanding factors that promote teachers' ICT use and using ICT to promote development of positive student identity and agency in mathematics.

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