Integration of ICT in the Mathematics Classroom

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Abstract

Students and teachers now have a wider access to information communication technology (ICT) than before but the presence of ICT in the classroom does not equate to improved student outcomes. For the successful integration of ICT the role of the teacher is critical, because it is the teacher who decides when, where, how, and who, will use ICT. Evidence from the literature examined is that there are a range of factors affecting Teacher ICT integration of mathematics in the classroom. This review identifies some of these factors and recommends areas for future research.

Keywords: ICT Integration, Teacher ICT background, Student Outcomes.

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Introduction

In the past 20 years there has been a significant increase in information communication technology (ICT) investment in education, so students and teachers now have a much wider access to ICT than before (OECD, 2015). The reason for the investment is the belief that introducing ICT will improve teacher productivity, student outcomes, and prepare students for a world where technology is an important part of life. Governments have also mandated the importance of ICT in education. The New Zealand Ministry of Education Curriculum declares that "Our vision is for young people ... who will seize opportunities offered by new knowledge and technologies" (Ministry of Education, 2015, p. 8).

Recent research has shown that teacher integration of ICT into mathematics classroom has an impact on student outcomes (Hegedus, Tapper, & Dalton, 2016). The availability of technology in classrooms alone does not improve student outcomes. It is the teacher's decisions on how to integrate ICT into the mathematics class room that will either improve or hinder student outcomes. Given the importance of the teacher in integration of ICT in the classroom, the literature has developed a range of theoretical frameworks to understand ICT integration by mathematics teachers.

The objective of this literature review is to analyse some of the factors affecting teacher ICT integration of mathematics in the classroom identified by the literature. The literature can be classified into three paradigms: *micro models*, factors related to the teacher and technology; *macro models*, environmental factors; and *integrative models* that combine teacher beliefs and background with elements of the micro and macro models (Olive, 2011).

The Technological Pedagogical Content Knowledge (TPACK) framework focuses on the knowledges required by teacher (Mishra & Koehler, 2006). *Instrumental orchestration* describes the processes used by teachers to gain ICT competency and develop competency in their students (Ruthven, 2009). Instrumental orchestration and TPACK fall within the micro model of classification through their focus on teacher and student use of ICT. The Practitioner Model of Computer (PMC) uses model analyses and external factors, including the working environment, resource system, activity structure, and curriculum script (Ruthven, 2009), and it is an example of a macro model.

The sociocultural framework and Technology Acceptance Model (TAM) are examples of integrative frameworks. The sociocultural framework describes interaction between the teacher's Zone of Proximal Development (ZPD), Zone of Free Movement (ZFM), and Zone of Promoted Action (ZPA), (Goos, 2010). The TAM is built on the interaction between instructional, curricular, and organisational factors, affecting the teacher's integration of technology (Okumuş, Lewis, Wiebe, & Hollebrands, 2016).

The studies in this review were chosen to demonstrate the efficacy of each theoretical paradigm and shed light on the factors that influence mathematics teachers on ICT integration.

Micro Factors

The TPACK framework for ICT integration was introduced by Mishra and Koehler (2006). The model has three elements Pedagogical Knowledge (PK), Content Knowledge (CK), and

Technical Knowledge (TK). Pedagogical knowledge refers to the knowledge of the teacher of how to teach, content knowledge describes what is taught, and technical knowledge is the teacher's knowledge of technology. Combinations of three domains produce Pedagogical Content Knowledge (PCK), Technical Content Knowledge (TCK), and Technical Pedagogical Knowledge (TPK). TPACK is at the centre of PCK, TCK, and TPK, and represents the amalgamation of all three knowledges into teacher practice (Stoilescu, 2014). TPACK provides a means of understanding the use of technology in the classroom by providing a way to understand the development of instructions before they are used in the classroom.

Teachers whose ICT integration is consistent with TPACK, are committed to innovate their practice and pedagogy through technology, support students and their colleagues to understand the value of technology, and understand the value of technology in class management and assessment (Grandgenett, 2008). Guerrero (2010) conducted a study of Barbara, an experienced Californian secondary mathematics teacher, whose practice showed the applicability of TPACK. Barbara viewed her role as delivery of the curriculum and preparation of her students for a world where technology played a significant part. Her teaching practice emphasised collaborative learning, where technology enabled students to access content and carry out their own enquiry.

The integration of TPACK in secondary mathematics classroom contexts was explored among 280 secondary mathematics teachers in 123 secondary schools in urban and rural New South Wales, Australia (Handal, Campbell, Cavanagh, Petocz & Kelly, 2013). The study determined the level of TPACK in a 30 question written survey called TPCK-M. The questions were designed to identify the nature and magnitude of the teacher's TCK, PCK, and TPACK, and to identify how instructional, curricular, and organisational factors affect ICT integration in the context of the TPACK model. From this study authors concluded that although teachers had fairly good standards of technological skills across the mathematics domain (TPCK-M) teachers needed to be trained in the use of innovative learning technologies because this was inhibiting the use of them in the classroom. (Handal et al., 2013). The transfer of TPACK to the classroom was a complex process, as teachers revealed that student ability, curriculum, and pressure to deliver were among factors affecting ICT integration in the mathematics classroom (Handal et al., 2013).

Archambault and Barnett (2010) were critical of the TPACK framework, specifically questioning its validity and applicability. In their study of 596 online teachers from the United States of America they found it challenging to separate out the different domains of the TPACK framework and noted that "TPACK creates boundaries…and already ambiguous lines drawn between pedagogy and content knowledge" and they gave the results of the survey they conducted as supporting evidence of this (p. 1658). Understanding the components and their interaction for each teacher was difficult.

Instrumental Orchestration

The instrumental orchestration framework describes ICT integration through the lens of the processes used by the teacher to acquire ICT competence and to develop the ICT competence of their students. Initially, the teacher is a novice in the use of ICT (for example, the use of graphics calculators). During a process known as instrumental genesis (Ruthven, 2013) the teacher develops the capability to use the technology and include it within their pedagogy. This process is described by Ruthven as an *instrumental approach* where the "tool and person co-evolve so that what starts as a crude "artefact" becomes a functional "instrument" and the person who starts as a naive operator becomes a proficient user" (2013, p. 7).

Instrumental orchestration describes the strategies used by teachers to orchestrate student integration of ICT, where the students instrumental genesis is within a continuum from novice to expert. Teachers employ a range of strategies to promote student ICT capability. Instrumentation orchestration was described in a study carried by Drijvers, Doorman, Boon, Reed, and Gravemeijer (2010). The context of the study was the trialling of an application designed to produce a graphical representation of a function as an input-output device. Teachers in 29 eighth grade classrooms in one Belgium and nine Dutch schools participated in three research cycles. The study identified a range of instrumental orchestration strategies including: technical demonstration, explain the screen, link screen-board, discuss the screen, spot and show, and Sherpa at work. Technical demonstration is the demonstration of technical features by the teacher. Explaining the screen refers to the teacher explanation of technique and mathematical context. Linking screen-board is the link between the representation on the screen and other media (including textbooks). Discussing the screen is the teacher led discussion about what the screen is showing. Spot and show is the use of an example of student work using the application to provoke discussion in the class. Sherpa at work is the situation where a student is selected to demonstrate their work on the screen (Drijvers et al., 2010). The forms of orchestration were related to traditional teacher practice, suggesting that teacher integration of Digital Mathematics Environment (DME) (and other forms of ICT) is evolutionary and follows a process of teacher acquisition of competence in ICT and subsequent development of strategies to facilitate student use of technology (Drijvers et al., 2010).

Macro Factors

Practitioner Model Of Computer (PMC) Use

The use of PMC in school mathematics is designed to take a holistic view of the factors associated with the successful integration of ICT in the mathematics classroom. The PMC model was developed through group discussions with seven group interviews with mathematics departments in the first half of 2000 (Ruthven & Hennessy, 2002). Studies of graphics software in the United Kingdom (Ruthven, Deaney, & Hennessy, 2009), and use of the Class Response System (CRS) by Swedish mathematics teachers have investigated the applicability of the PMC (Gustafsson, n.d.).

During construction of the PMC model, teachers identified the following as factors affecting ICT integration: working environment, resource system, activity structure, curriculum script, and time economy. Working environment describes impact of ICT integration on the physical environment for teaching, in some cases ICT integration required moving the students to a computer laboratory, resulting disruption and loss of time. Resource system refers to the coordination between ICT tools and other resources in the lesson. Curriculum script refers to the change in organisation of lesson delivery due to the inclusion of ICT. Time economy describes the reduction in time required for student learning attributed to the integration of ICT (Ruthven, 2013).

In the context of the PMC framework Ruthven et al., (2009) studied how two English mathematics teachers integrated graphics ICT effectively into their classrooms. Initially the teachers demonstrated the software to their students and explained the mathematical context of the results. Both teachers encouraged their students to explore the software, enabling them to build confidence in their use of the software and have fun. By removing the task of producing the graphs from the learning task enabled the teachers to focus on the conceptual issues associated with the lesson. Students preferred the software to the traditional pen and paper and became more engaged with the content. The study showed benefits from the software accrued when teachers included software mediated learning tasks into their lessons, supported students to explore and understand the software, and then changed the structure of their curriculum script to include the software based tasks for students (Ruthven et al., 2009).

The PMC framework was applied to a sample of secondary school mathematics teachers in Sweden. The teachers had received the CRS, a system designed to enable teachers observe student responses simultaneously. Participants in the study received training in the CRS system, and were given tasks designed to promote classroom discussions and student learning. The study showed that the PMC framework captured a substantial part of teacher reasoning concerning technology integration. Most of the teacher responses fell within the framework. However, the framework did not discuss the impact of the student attitudes and behaviours on the process of the CRS integration. For example, some teachers had difficulty when students responded to a question without waiting for others in the class (Gustafsson, n.d.).

Integrated Models

Sociocultural Framework for Understanding

Sociocultural theories view learning as an interaction between societal and environmental factors within and outside of the classroom. This interaction promotes understanding of the factors effecting integration of technology into the mathematics classroom (Goos, 2010).

The sociocultural framework for understanding technology integration in secondary school mathematics is an adaptation of Valsiner's zone framework (Valsiner, 1997). Valsiner's zone framework extends Vygotsky's concept of ZPD to the ZFM and ZPA. The Zone of Proximal Development (ZPD) describes the gap between current and potential capabilities of learners that can be traversed with appropriate support. The Zone of Free Movement (ZFM) refers to constraints that affect the ways an individual can interact with their environment. And the Zone of Promoted Action (ZPA) describes the efforts of an experienced learner, who is developing new skills. In the context of the sociocultural framework, the ZPD refers to mathematics pedagogy, pedagogical beliefs concerning technology, and experience in working with technology. The ZFM describes ICT access and support at school, perceived student attitudes and ability, curriculum and assessment requirements. And the ZPA includes university education, practical teaching experience and professional development courses (Goos, 2006).

The efficacy of the sociocultural framework in understanding the interactions between pedagogy, teacher backgrounds and beliefs, school structure, and institutional frameworks was analysed through classroom episodes and professional development experiences of teachers (Galbraith & Goos, 2003), a study of lead teachers in the integration of ICT into mathematical practice (Goos & Bennison, 2008) and pre-service teachers at Queensland University (Goos, 2005). The studies showed that the interaction of all three zones had an impact on the integration of ICT into the classroom. Teachers with a strong ZPA had developed ICT confidence and competence through pre-service training, attending professional development courses, and assistance from colleagues and professional associations. The desire to promote student mathematical understanding through technology, constructivist pedagogy, and real world application were identified as elements of a strong ZPD. Support from departmental and school leadership were elements associated with a supportive ZFM. The studies (Galbraith & Goos, 2003; Goos, 2005; Goos & Bennison, 2008) showed that teachers from schools with poor ICT resources could overcome this through their desire to embrace technology (ZPA) and support student learning (ZPD). However, teachers from schools with rich ICT could retard the ICT integration through a lack of desire to embrace ICT in their practice (Goos & Bennison, 2008).

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was initially developed for use in industry to identify the willingness of workers to incorporate new technology, based on perceptions of usefulness and ease of use. Perceived usefulness is the improvement in performance from new technology, perceived ease of use refers to the reduction in effort resulting from the introduction of the new technology. Factors affecting ICT integration by mathematics teacher can be classified as: instructional, curricular, and organisational (Handal, Campbell, Cavanagh, Petocz, & Kelly, 2013). Instructional factors include teacher's belief of the value that ICT will bring to student learning. Curricular factors describes the effort made to align ICT with curricula and other resources. Organisational factors refer to the actual and perceived support for ICT integration. The three factors link the context of industry to the classroom where the teacher is making decisions about ICT integration on the basis of its perceived usefulness and ease of use (Okumuş et al., 2016).

Stols and Kriek (2011) use the TAM model to investigate the integration of dynamic mathematics software into 24 South African Grade 10-12 mathematics classrooms. The study used TAM, Theory of Planned Behaviour, and Innovation Diffusion Theory to identify teacher beliefs concerning integration of dynamic mathematics software. Data collected in the study was modelled using stepwise regression analysis that was through partial least squares. Results of the study showed that teacher beliefs concerning the perceived utility of dynamic mathematics software and their proficiency in using the software were the most significant factors in explaining actual and intended use of the software (Kriek & Stols, 2011)

Conclusion

Integration of ICT by mathematics teachers has been demonstrated to significantly impact student progress. The role of the teacher in deciding when, how, and where to use ICT will determine whether its use will facilitate student learning of mathematics. The literature on the adoption of ICT integration has shown that the factors affecting ICT integration fall within three paradigms: interaction between the teacher and technology (micro model), interaction between teacher, technology and the environment the teacher performs (macro model), interaction between teacher beliefs, ability to improve ICT competence, and their environment (integrative model) (Goos & Bennison, 2008; Okumuş et al., 2016).

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