RUNNING HEAD: MATHEMATICS TECHNOLOGY RESEARCH

Research in Mathematics Instructional Technology: Current Trends and Future Demands

Robert N. Ronau and Christopher R. Rakes

University of Louisville

Margaret L. Niess

Oregon State University

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Abstract

This paper presents the results of a systematic review of literature in which the authors examined instructional technology integration in mathematics. Three lenses were used to examine the treatment of teacher knowledge as it relates to technology implementation in mathematics: a research design framework, a teacher knowledge framework (CFTK), and a technology integration framework (TPACK). TPACK offers a balance of developmental levels of technology integration by providing a structure for focus and scale, whereas CFTK facilitates the examination of intricate interactions of teacher knowledge aspects. Combined with a critical view of research design, these tools provide educators a robust perspective for analyzing the effectiveness of instructional technology methods and bringing the best tools to the classroom.

RESEARCH IN MATHEMATICS INSTRUCTIONAL TECHNOLOGY: CURRENT TRENDS AND FUTURE DEMANDS

Teachers use instructional technology for online courses, video conferencing, electronic portfolios, and other exploratory projects. Literature reviews are important tools that teachers can use to evaluate instructional technology and develop strategies for its effective use. A systematic review of literature can make such evaluations far easier and more effective by synthesizing the results of the studies on a given topic using transparent methodological processes. The purposes of this study are (1) to systematically and structurally synthesize existing studies on the impact of technology on teaching and learning mathematics using seven frameworks to provide structure to the review (TPACK, CFTK, Research Design, NCTM Principles, NCTM standards, sources of data, and outcomes) and (2) to determine the utility of each framework for such a synthesis. This analysis will attempt to answer at least ten questions.

1. What is the overall structure of research in mathematics instructional technology?
2. What is the overall nature of the research findings in mathematics instructional technology?
3. How can data sources used in mathematics instructional technology research be categorized?
4. What are the key outcomes from papers in mathematics instructional technology (organized by frameworks)?
5. How do data source categories align with study outcomes in mathematics instructional technology research?
6. How can teacher and student outcomes in mathematics instructional technology research be categorized?

7. What NCTM Principles are addressed in mathematics instructional technology research? To what degree, how, implicit/explicit.
8. Which TPACK Standards are addressed in mathematics instructional technology research?
9. What aspects of teacher knowledge are addressed in mathematics instructional technology research?
10. To what degree do the seven frameworks capture the scope of mathematics instructional technology research?

This study is a work in progress. A pilot study of a random sample of studies from five content areas has been completed (Ronau et al., in press). Based on the results of the pilot, a new literature search was conducted to focus exclusively on mathematics educational technology. A new coding protocol was developed through an iterative process, and the sample studies are currently being coded using the new protocol.

Research Design

The complex nature of questions pertaining to instructional technology effectiveness requires a variety of research designs such as (1) experimental or quasi-experimental studies, (2) large-scale studies, (3) studies with sufficient statistical information to be included in meta analysis and mixed-methodology studies, (4) studies with rich analysis of student content knowledge, and (5) studies that address the complexities of learners, classrooms, and schools (Bell, Schrum, & Thompson, 2009; Means, Wagner, Haertel, & Javitz, 2003). In addition to research design, this study is also interested in how previous studies have taken into account the impact of teacher knowledge on the effectiveness of technology in the classroom. Within the past few years, two new teacher knowledge frameworks have been proposed that have the potential to support the research community in responding to questions on the impact of technology on learning. The Comprehensive Framework of Teacher Knowledge (CFTK) provides a three-dimensional model of teacher knowledge (Ronau, Rakes, Wagener, & Dougherty, 2009; Ronau, Wagener, & Rakes, 2009; Ronau et al., 2009). The Technology, Pedagogy, And Content Knowledge (TPACK) framework focuses on teachers' interconnected and interrelated knowledge of content, pedagogy, and technology (Mishra & Koehler, 2006; Niess, 2005).

Comprehensive Framework of Teacher Knowledge

CFTK emerged from a recognition of the need to capture complex interactions of teacher knowledge aspects that were not currently defined by any single framework in existence (Ronau & Rakes et al., 2009; Ronau, Wagner, & Rakes, 2009; Ronau & Taylor et al., 2009). Through a survey of literature, Ronau & Taylor et al. (2009) found that research had identified three key components of teacher knowledge, each composed of two interrelated aspects. A three-dimensional arrangement was found to best portray the intricate system of interactions between the aspects of the three components while the cross-sections of the model maintain the ability to describe the unique intersections within each of the three key components. These three key components became the three dimensions of CFTK: Field, comprised of the aspects Subject Matter Knowledge and Pedagogical Knowledge; Mode, consisting of the aspects Discernment and Orientation; and Context, composed of the aspects Individual and Environment (Figure 1). This developing framework provides an initial structure to address the need for clear articulation of multifaceted interactions of teacher knowledge.

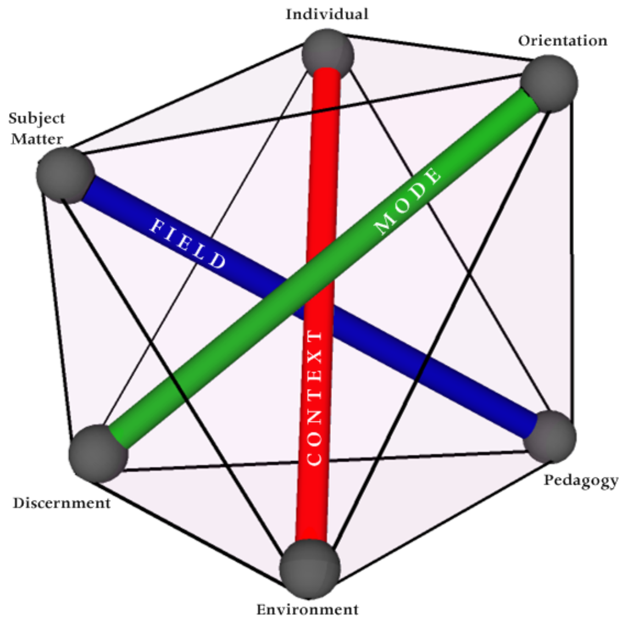

Figure 1. CFTK framework of teacher knowledge as a three-dimensional structure.

The first dimension of CFTK, Field, represents PCK as one of many possible interactions within teacher knowledge. Subject matter and pedagogy also interact with teacher knowledge of Mode and Context to better capture the complexity of interplay between all three dimensions.

The second dimension of CFTK, Mode, describes the knowledge teachers rely on to navigate the cognitive and affective characteristics of their students. *Orientation* describes the knowledge teachers retrieve to understand how affective issues (e.g., beliefs, dispositions, values, goals) impact the effectiveness of teaching activities. *Discernment* refers to the knowledge essential for teachers to account for the effect of student cognitive, metacognitive, inquiry, and reflective development on learning (Davis, 1992; Schoenfeld, 1982, 1992; Schön, 1995). Schoenfeld (1982) proposed that the effects of the cognitive and affective domains on learning are intertwined. Likewise, teacher knowledge of these domains must also incorporate that intersection. Furthermore, the knowledge of affect and cognition “must take into account the context in which [they] are embedded” (Schoenfeld, 1982, p. 31).

The third dimension of CFTK, Context, describes the knowledge teachers need to manage the influence of different types of context and their interactions with Mode, Field, and their interactions. The Individual aspect of CFTK refers to the knowledge teachers engage to manage the effects of student characteristics (e.g., Gender, age, SES, learning styles, temperament) on a learning situation. The CFTK aspect Environment addresses the knowledge teachers require to manage the impact of factors external to the learner that may influence learning such as school or classroom climate, student relationships, and school or class organizational structures and procedures (Davis & Simmt, 2003; Davis & Sumara, 1997, 2001; Ding & Sherman, 2006). Furthermore, CFTK also describes the knowledge teachers need to manage the interactions of Environment with Individual, Orientation, Discernment, Subject Matter, and Pedagogy.

Technology, Pedagogy, and Content Knowledge

Initially, the knowledge framework of Technological Pedagogical Content Knowledge (TPCK) was proposed as a complex interaction among three bodies of knowledge – technology, pedagogy, and subject matter content (Mishra & Koehler, 2006; Niess, 2005). Late in 2007, TPCK was recast as TPACK, or the "total package" required for integrating technology, pedagogy, and content knowledge in the design of instruction for thinking and learning with technology; this recasting acknowledged the importance of the interactions between the individual constructs of the model technologies (Niess, 2008; Thompson & Mishra, 2007).

The TPACK framework provides a structure to guide research into the nature and development of teacher knowledge for teaching with technologies. Niess and colleagues (Niess, Lee, Sadri, & Suharwoto, 2006; Niess, Lee, & Sadri, 2007; Niess et al., 2009) described teacher growth for technology integration in the classroom through five progressive stages: (1) Recognizing, (2) Accepting, (3) Adapting, (4) Exploring, and (5) Advancing. Figure 2 portrays the levels that teachers engage in as they expand their knowledge and understandings in ways that merge multiple knowledge bases - technology, content, and pedagogy.

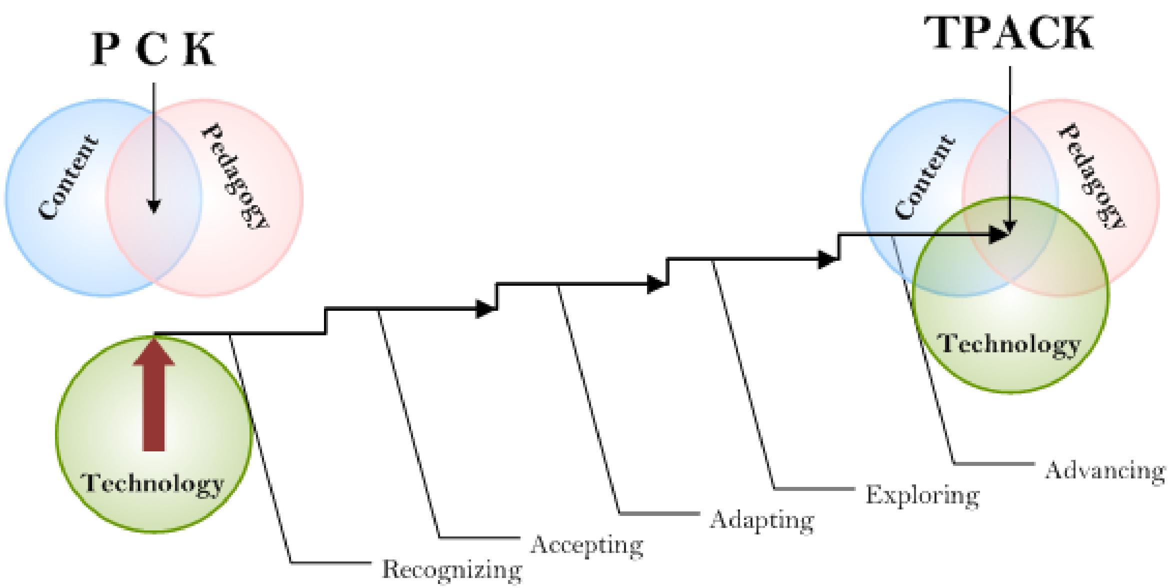

Figure 2. Model of teacher thinking and understanding as that knowledge develops toward the intersection identified as important by TPACK.

On the left side of the graphic, the figure highlights PCK as the intersection of pedagogy and content. As the knowledge of technology expands and begins to intersect with pedagogical and content knowledge, the teacher knowledge base described as TPACK emerges: This is a space in which teachers actively engage in guiding student learning of mathematics with appropriate technologies.

TPACK also provides a framework for technology implementation in mathematics education. The American Mathematics Teacher Educators (AMTE) association recently adopted a set of four technology guidelines based on TPACK (Ronau, 2009, p. 12):

1. Design and develop technology-enhanced mathematics learning environments and experiences.
2. Facilitate mathematics instruction with technology as an integrated tool.

3. Assess and evaluate technology-enriched mathematics teaching and learning.
4. Engage in ongoing professional development to enhance technological pedagogical content knowledge.

Integrating CFTK and TPACK

These two frameworks may seem to be competing images of the knowledge base teachers need for teaching with technology. However, a combination of the two frameworks may enhance our understanding of how technology integration and teacher knowledge interact in a learning environment. TPACK defines a teacher knowledge framework further described by a series of levels for technology integration while CFTK provides insight into the teacher knowledge aspects and their interactions needed to address the TPACK Guidelines.

NCTM Principles

Based on the pilot study results, we added a section to the protocol to code the six principles from the National Council of Teachers of Mathematics (2000) and whether these principles were addressed explicitly in the study. These six principles are Learning, Teaching, Assessment, Technology, Curriculum, and Equity. The Learning Principle states the importance of the development of mathematics understanding and the connection of new knowledge with experience and prior knowledge. The Teaching Principle emphasizes the connection of pedagogy to meeting student needs and the development of challenging tasks to support learning. The Assessment Principle focuses on the importance of assessment as a tool to support learning. Likewise, the Technology Principle views the use of digital tools as an essential component for developing deep understanding of mathematics concepts. The Curriculum Principle supports the development of coherent, well-articulated collection of activities that focus on important mathematics ideas. The Equity Principle states that high levels of mathematics learning requires high expectations for all students along with the support needed to meet those high expectations regardless of personal challenges. These principles were included in the coding protocol as an attempt to capture philosophical underpinnings of research in mathematics educational technology.

NCTM Standards

Based on feedback from previous conference sessions (Rakes, Wagener, & Ronau, 2010), a section for coding the type of mathematics being examined in each study was included. We chose to use the NCTM (2000) Standards for two reasons. (1) The standards are easily connected to the NCTM Principles already being coded. (2) State and local mathematics curriculum standards vary widely (Reys, Reys, & Lappan, 2003) while the NCTM standards are a nationally recognized guideline used by many states and local districts.

Methods

We began our systematic review by asking what types of research designs were used and how well the CFTK and TPACK models explained the teacher knowledge needed to integrate technology effectively in mathematics. Three criteria were used to select studies for the review: (1) Studies were found in scholarly, peer-reviewed journals, reports, dissertations, or conference proceedings, (2) Studies involved the use of technology in an educational setting, and (3) Studies focused on mathematics education.

Several electronic databases related to education and psychological sciences were searched. These included the EBSCOhost databases: Academic Search Premier, Education Administration Abstracts, ERIC, Middle Search Plus, Psychology and Behavioral Sciences Collection, PsycINFO, Sociological Collection, and Teacher Reference Center; two H.W.

Wilson databases: Education Full Text and the Social Sciences Index; JSTOR; five ProQuest databases: Career and Technical Education, Dissertations & Theses, Ethnic NewsWatch, GenderWatch, and Research Library; the IEEE Electronic Library; and three ISI Web of Knowledge databases: the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts and Humanities Citation Index. Search terms were divided into three categories: type of technology, education, and mathematics (Table 1). The literature search identified 1,368 manuscripts that presented results of research and 430 non-research manuscripts (e.g., book reviews, pedagogical strategy description, activity descriptions).

Types of Tech	Education	Mathematics
Technology	Education	math*
Calculators	Teach	geometry
Software	Learn	algebra
Sketchpad	Class	fraction
Geogebra	school	rational
WinGeom	Student	number
Cabri	College	integer
TI	Train	variable
Digital or Dynamic		function
Virtual		equation
Applet		expression
Web		calc
Excel		probability
PowerPoint		statistics
Tablet		discrete
Computer		matrix
Podcast		coordinate
Distance Learning		transform
CBL/CBR		
Probe		
handheld or hand-held or hand held		
Visualization		
3D or 3-D		
Robot		

Analysis Strategies

Studies identified with a quantitative research design were coded as being either randomized or quasi-experimental. We will also recorded outcome measures, reliability measures, and validity measures as well as selection mechanisms and use of measures to control pre-existing differences. Studies identified as qualitative were coded by their research design (e.g., narrative/historical, biography, design study, phenomenology, ethnography, grounded theory, or case study), the methodology employed (e.g., covert/overt observation, interview, or focus group), alignment of the study methodology with outcome(s) of interest, and evidence of trustworthiness. For studies with the purpose of theory development, we recorded as much applicable information as possible and marked the rest as “not applicable.” Inter-rater reliability was managed in two ways. First, to reduce as much variation as possible in coding decisions, we developed coding tables with closed response systems. Second, each study was coded by at least two people.

Initial Results

In the pilot study, we found that a wide variety of technology was discussed (e.g., computers, computer software, online courses and course materials and grading, web-based learning environments, multimedia, and interactive whiteboards) with over half of the studies focusing on computers and the Internet.

Research Design

In three studies, approximately 10% of the pilot sample, methodology was either not addressed or lacked sampling information such as sample sizes (Hayes & Mayerick, 2001; O‘Connell & Phye, 2005; Zucker, Tinker, Staudt, Mansfield, & Metcalf, 2008). In light of other calls for better methodological reporting (e.g., McCoy, 1998; Mervielde, 1977; Nowak, 1969; Triandis, 1976), we concluded that these studies may indicate a general weakness in the research literature. So, not only are there gaps in the existing literature, but the studies that have been completed in this area may be limited by their design and the information they provide. As a result, educators are left to evaluate the effectiveness of any particular type of instructional technology on their own without a dependable research foundation. We identified 50% of the pilot sample as non-research, 33% qualitative, 17% quantitative, and 0% mixed methods. The non-research papers were mostly composed of instructional strategies (40%), followed by theory development (33%), anecdotal description (20%), and book reviews (7%).

CFTK Aspects

Fifteen studies in the pilot sample (50%) addressed teacher knowledge in some manner. Only five of the 15 addressed knowledge of Individual Context while only three of the 15 included knowledge of Discernment. Because technology tools often rely heavily on each of these strategies, the lack of research to address the effects of teacher knowledge of orientation, discernment with respect to contextual differences limits the ability of that research to adequately address the needs of educators wishing to integrate technology effectively.

TPACK Stages

The pilot sample demonstrated a high degree of emphasis on technology integration (25 of the 30 studies). Eighteen of the 30 studies addressed the highest stage of TPACK (Advancing).

Discussion

Pilot Results

These pilot results suggest the need to examine the use of mixed methodology designs in mathematics education. Furthermore, we examined the treatment of teacher knowledge as it related to technology implementation in mathematics. Further use of the CFTK and TPACK frameworks combined with a consideration for design and methodology offer a useful structure to examine educational technology research in ordered detail. TPACK offers a balance of developmental levels of technology integration by providing a structure for focus and scale, whereas CFTK facilitates the examination of intricate interactions. Combined with a critical view of research design, educators have a robust tool for analyzing the effectiveness of instructional technology methods and bringing the best tools to the classroom.

Current Status of Project

We have completed the calibration of the coding protocol through an iterative process of group codings. The whole group coded five manuscripts and then met to discuss strengths/weaknesses of the protocol. Once the protocol was adjusted, we coded 10 more papers and re-calibrated the protocol. Once this stage was completed, the new protocol was presented at the 2010 annual meeting of the American Mathematics Teacher Educators (AMTE; Rakes, et al., 2010). Based on feedback from this meeting, the protocol was revised again. The research team coded 10 more papers using the newest protocol and completed one more round of protocol revisions. The remaining sample of the 1,368 studies was then divided among the team members, and those manuscripts are currently being coded.

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