Research in Mathematics Instructional Technology

Current Trends and Future Demands

Purpose and Research Questions

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?**

Sample

Whole Book	18
Book Chapter	83
Conference Proceedings	12
Report	66
Journal	570
Dissertation	611
Research N	1360
Non-Research N	430
Total N	1790

Frameworks

1. Outcomes
2. Teacher Knowledge
3. TPACK
4. Data Sources
5. Research Design
6. NCTM Principles
7. NCTM Standards

Types of Technology

Calculators/Probes:

- ☐ Non-Scientific
- ☐ Scientific
- ☐ Graphing
  - ☐ TI-73/73+
  - ☐ TI-80/81/82
  - ☐ TI-83/83+
  - ☐ TI-84/84+/84+SE
  - ☐ TI-85/86
  - ☐ TI-89
  - ☐ TI-92/92+/Voyage 200
  - ☐ TI-NSpire
  - ☐ Casio FX-9860G/GII/GSlim
  - ☐ Casio ClassPad 300/330
  - ☐ Casio FX-9750GII/GAPlus
  - ☐ Casio FX-7400G/GPlus
  - ☐ HP 10s/33s/35s/39gs/40gs/48gII/50g
  - ☐ HP SmartCalc 300s
  - Other Graphing Calculator:
- ☐ Programming
- ☐ Apps
- ☐ CAS
- ☐ Document Management
- ☐ Symbolic Algebra
- ☐ Simulation
- ☐ Symbolic Calculus
- ☐ Statistics
- ☐ Networked-Handheld Devices
- ☐ Dynamic Geometry

Computer Software:

- ☐ Dynamic Geometry Software
- ☐ Graphing Software
- ☐ Algebraic Software
- ☐ Statistical Software
- ☐ Statistical Instructional Software
- ☐ Spreadsheet Software
- ☐ Presentation Software
- ☐ Applet Software
- ☐ Game/Puzzle Software
- ☐ Testing Software
- ☐ Tutorial Software
- ☐ Student Response System
- ☐ SmartBoards

Probes:

- ☐ Probeware

Internet:

- ☐ Virtual Manipulatives
- ☐ Online Applets
- ☐ Distance Learning
- ☐ Online Games/Puzzles
- ☐ Online Testing Software
- ☐ Online Tutorial Software
- ☐ Web Sites
- ☐ WebQuests
- ☐ Wiki Spaces
- ☐ Facebook/MySpace/Twitter
- ☐ Video Conferencing (e.g., Skype, Windows Messenger)
- ☐ Document Sharing
- ☐ Online Video Sharing
- ☐ Blogs

Other Technology (Not Described Elsewhere):

Outcomes

Description of the Outcome of Interest *(Mark all that are measured or reported outcomes of the study)*

Student Outcomes (Check all that Apply):

- ☐ Achievement
- ☐ Learning, Conceptual
- ☐ Learning, Procedural
- ☐ Orientation (i.e., affective domain)
- ☐ Discernment (i.e., cognitive domain)
- ☐ Behavior *(In math class context; e.g., dialog, role, collaboration, problem solving approaches - referrals and other non-math course specific behaviors are not part of this category)*
- ☐ No Student Outcomes

Teacher Knowledge Outcomes (Check all that Apply):

- ☐ Subject Matter (Knowledge of Mathematics)
- ☐ Pedagogical (Knowledge of Teaching)
- ☐ Discernment (Knowledge of Cognitive Domain)
- ☐ Orientation (Knowledge of Affective Domain)
- ☐ Individual Context (Knowledge of Within-Person Effects)
- ☐ Environmental Context (Knowledge of Outside-of-Person Effects)
- ☐ No Teacher Knowledge Outcomes

Teacher Orientation Outcomes:

- ☐ Attitudes, beliefs, efficacy towards mathematics, teaching, students, etc.
- ☐ No Teacher Orientation Outcomes

Teacher Behavior Outcomes:

- ☐ Teaching Choices Reflect Best Practices
- ☐ Professional Activities
- ☐ No Teacher Behavior Outcomes

Other Outcomes (Not Addressed in Student/Teacher Outcomes):

- ☐ Can't Tell
- ☐ Analysis of Instrument
- ☐ Report of Classroom or Teaching Activity
- ☐ Research to Practice

Other Outcome(s):

Describe the Important Conclusions/Findings of the Paper:

TPACK Stages

TPACK Standards/Guidelines Addressed *(Mark all that Apply)*

- ☐ Design and develop technology enhanced mathematics learning environments and experiences
- ☐ Facilitate mathematics instruction with technology as an integrated tool
- ☐ Assess and evaluate the impact of technology enriched mathematics teaching and learning
- ☐ Engage in ongoing professional development to enhance technological pedagogical content knowledge
- ☐ Not Addressed
- ☐ Can't Tell

Were the TPACK standards addressed explicitly or implicitly?

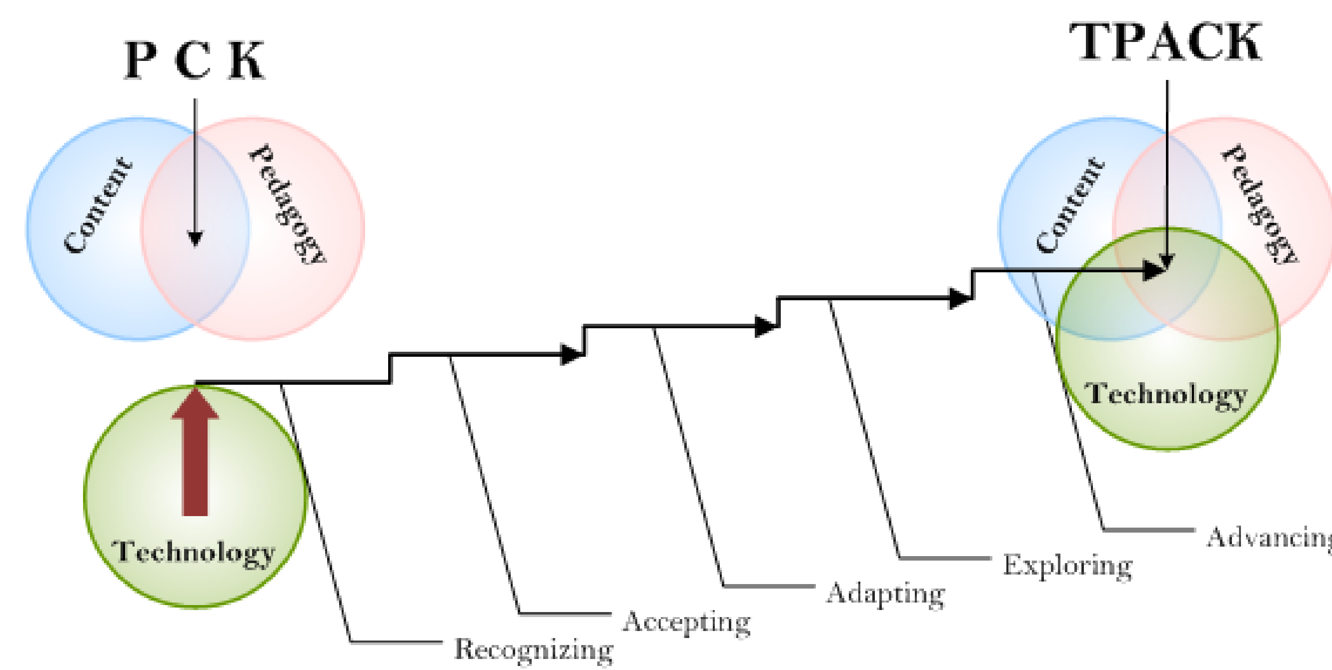
TPACK Stages/Subsets Addressed

Highest TPACK Stage addressed by the outcome of interest.

Was this stage addressed explicitly or implicitly?

TPACK Subsets Explicitly Addressed by the Outcome of Interest (If TPACK Not Addressed Explicitly)

☐ TPK ☐ TCK ☐ PCK ☐ TK ☐ PK ☐ CK ☐ Not Addressed/Applicable

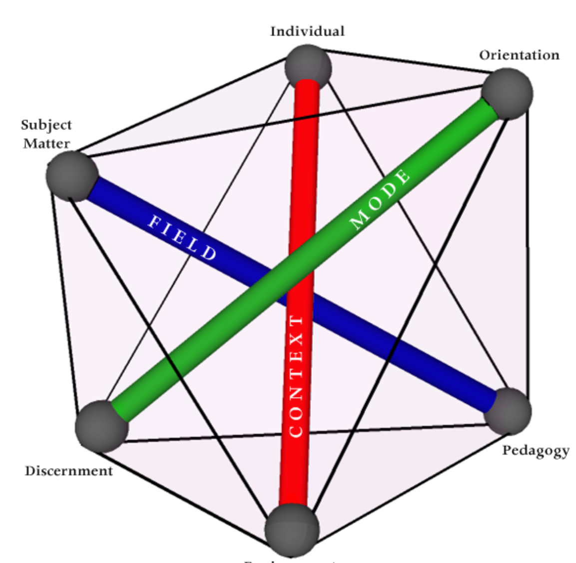


Data Sources

Source of Data *(Mark all that Apply)*

- ☐ Assessment Data (e.g., Achievement, Grades, Performance)
- ☐ Content Analysis Data
- ☐ Observation Data
- ☐ Interview Data
- Journal Data:
  - ☐ Researcher Journal
  - ☐ Subject Journal
  - ☐ Non-Researcher/Non-Subject Journal (e.g., Teacher)
- ☐ Focus Group Data
- Self-Report Data:
  - ☐ Orientation Survey Data
  - ☐ Poll/Census Survey Data
- Other-Report Data:
  - ☐ Orientation Survey Data
  - ☐ Polls/Census Survey Data
- Other:

CFTK



NCTM Principles and Standards

NCTM Principle Addressed by Outcome of Interest *(Mark all that Apply)*

- ☐ *Implicit* Learning (e.g., how students learn as opposed to how teachers etc. can impact learning)
- ☐ *Implicit* Teaching (e.g., how changes in teaching, classroom environment, etc. impact outcome of interest)
- ☐ *Implicit* Equity (e.g., focus of intervention is that students of multiple backgrounds learn mathematics better)
- ☐ *Implicit* Technology (e.g., how technology inclusion in the math. classroom impacts student learning of math.)
- ☐ *Implicit* Curriculum (e.g., how a new/focused, coherent curriculum impacts student learning)
- ☐ *Implicit* Assessment (e.g., how assessment practices can be used to support teaching and learning of math.)
- ☐ NCTM Principles not addressed by Outcome of Interest

NCTM Standards Addressed by Outcome of Interest *(Mark all that Apply)*

- ☐ Number: Representations, Relationships, Systems
- ☐ Number Operations: Meaning, Relationships
- ☐ Number Computation: Fluency, Estimation
- ☐ Algebra: Patterns, Relations, Functions
- ☐ Algebra: Represent, Analyze Situations w/ Symbols
- ☐ Algebra: Math Modeling to Understand Relationships
- ☐ Algebra: Analyze Change in Contexts
- ☐ Geometry: 2D, 3D Shape Characteristics
- ☐ Geometry: Specify Locations, Coordinates
- ☐ Geometry: Transformations, Symmetry
- ☐ Geometry: Visualization, Spatial Reasoning, Modeling
- ☐ Measurement: Measurable Attributes, Units, Systems, Processes
- ☐ Measurement: Techniques, Tools, Formulas
- ☐ Data/Probability: Formulate Questions
- ☐ Data/Probability: Select Methods
- ☐ Data/Probability: Inference Prediction
- ☐ Data/Probability: Probability
- ☐ Problem Solving: Build New Knowledge
- ☐ Problem Solving: Solve Contextual Problems
- ☐ Problem Solving: Apply, Adapt Strategies
- ☐ Problem Solving: Monitor, Reflect on Process
- ☐ Reasoning, Proof: Recognition as Fundamental
- ☐ Reasoning, Proof: Make Conjectures
- ☐ Reasoning, Proof: Develop Argument, Proof
- ☐ Reasoning, Proof: Select Types, Methods
- ☐ Communication: Organize Mathematical Thinking
- ☐ Communication: Provide Coherence, Clarity
- ☐ Communication: Analyze, Evaluate Thinking
- ☐ Communication: Express Mathematical Ideas Precisely
- ☐ Connections: Recognition within Mathematical Ideas
- ☐ Connections: Math Ideas Produce Coherent Whole
- ☐ Connections: Math Ideas in Non-Math Contexts
- ☐ Representations: Organize, Record, Communicate Mathematical Ideas
- ☐ Representations: Select, Apply to Solve Problems
- ☐ Representations: Modeling, Interpreting Phenomena
- ☐ NCTM Standards Not Addressed

Qualitative Research Design

Sample Size: ____ Sample Units: ____

Type of Study

- ☐ Biography
- ☐ Narrative/Historical
- ☐ Design Study
- ☐ Phenomenology
- ☐ Ethnography
- ☐ Grounded Theory
- ☐ Case Study
- ☐ Can't Tell
- ☐ Other

Describe the Methodology

- ☐ Covert Observation
- ☐ Overt Observation
- ☐ Interview
- ☐ Focus Group
- ☐ Subject Dialog
- ☐ Document Analysis
- ☐ Can't Tell Method
- ☐ Other

Trustworthiness

- ☐ Persistent Observation
- ☐ Triangulation
- ☐ Peer Debriefing
- ☐ Negative Case Analysis
- ☐ Referential Adequacy
- ☐ Member Checks
- ☐ Thick Description
- ☐ Dependability Audit
- ☐ Confirmability Audit
- ☐ Reflective Journal
- ☐ Not Addressed

Quantitative Research Design

Research Design

Research Design: ____

Sampling Method: ____

Group Assignment: ____

Outcome Measure(s) Used:

- ☐ Validated Instrument from Literature
- ☐ Modified Instrument
- ☐ Instrument Designed for this Study
- ☐ Teacher-Made Instrument
- ☐ Behavior (e.g., Retention, Attendance)
- ☐ Standardized Instrument
- ☐ Grades
- ☐ GPA
- ☐ Graded Homework
- Other: ____

Sample Sizes

Total (Sum) Control Sample Size ("0" = Not Applicable): ____

Number of Control Groups: ____

Total (Sum) Treatment Sample Size: ____

Number of Treatment Groups: ____

Sample Units: ____

Type(s) of Reliability Addressed

- ☐ Internal Consistency
- ☐ Alternate Forms
- ☐ Split Half
- ☐ Test-Retest
- ☐ Can't Tell
- ☐ Not Addressed

Type(s) of Test Item Validity Addressed

- ☐ Construct Validity
- ☐ Content Validity
- ☐ Concurrent Criterion Validity
- ☐ Predictive Criterion Validity
- ☐ Convergent Validity
- ☐ Discriminant (Divergent) Validity
- ☑ Validity simply asserted or cited from test manual
- ☐ Validity confused with reliability
- ☐ Validity Not Addressed

Additional Comments about Validity/Reliability: ____

Threats to Validity Addressed

- ☐ *Implicit* Construct Validity Threats Addressed
- ☐ *Implicit* Internal Validity Threats Addressed
- ☐ *Implicit* External (Generalizability) Validity Threats Addressed
- ☐ *Implicit* Statistical Conclusion Validity Threats Addressed
- ☐ Threats to Validity Not Addressed

RUNNING HEAD: MATHEMATICS TECHNOLOGY RESEARCH

Research in Mathematics Instructional Technology: Current Trends and Future Demands

A paper proposal presented to the National Council of Teachers of Mathematics

Research Pre-session

April 19-21, 2010

Abstract

This study integrates three frameworks to examine the treatment of teacher knowledge as it relates to technology implementation in mathematics: research design framework, teacher knowledge (CFTK), and technology integration (TPACK). These frameworks provide a robust perspective for analyzing instructional technology effectiveness and improving classroom instruction.

Conceptual or Theoretical Perspective

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 well-articulated methodological processes. The purpose of this study is to examine the utility of integrating three lenses into a systematic review of instructional technology: 1) research design, 2) teacher knowledge, and 3) levels of implementation.

Research Design

The complex nature of questions regarding instructional technology effectiveness require 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).

Comprehensive Framework of Teacher Knowledge

CFTK (Ronau & Rakes et al., 2009; Ronau, Wagner, & Rakes, 2009; Ronau & Taylor et al., 2009) identifies six aspects of teacher knowledge, organized into a three-dimensional system (Figure 1) that captures complex interactions not defined by any other single teacher knowledge framework in existence. These three dimensions are: 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.

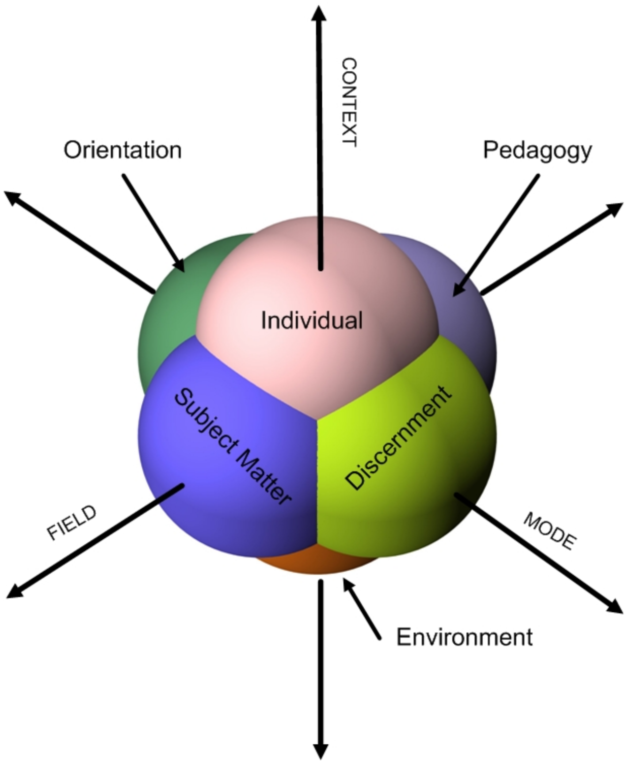


Figure 1. CFTK framework of teacher knowledge as a three-dimensional structure.

Technology, Pedagogy, and Content Knowledge

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.

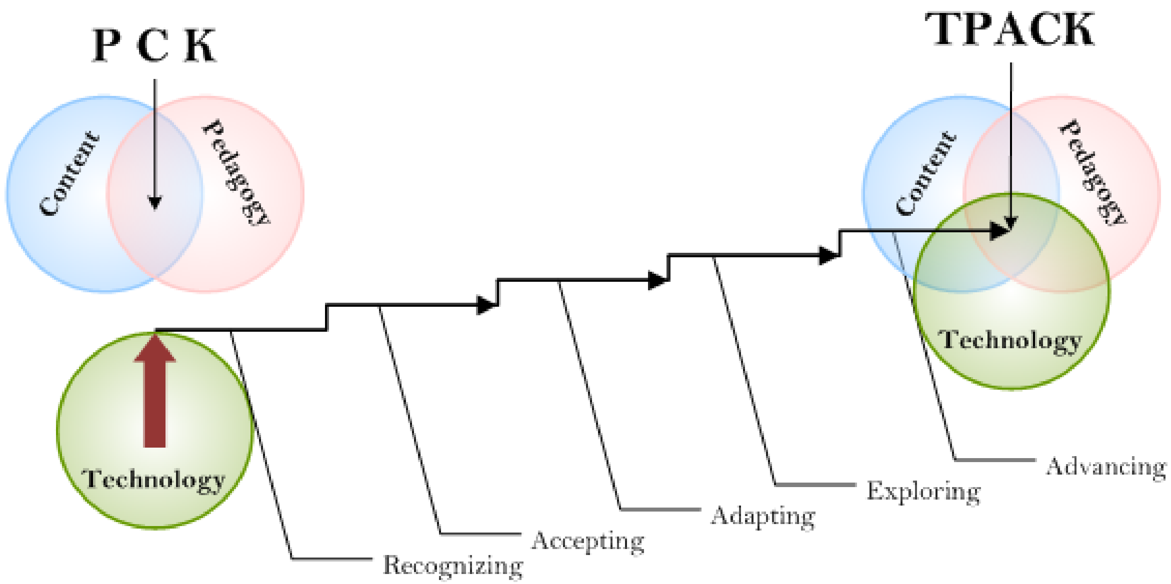


Figure 2. Model of teacher thinking and understanding as that knowledge develops toward the intersection identified as important by TPACK.

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.

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.

Research Question(s) and Design

In this review, we asked 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.

Data Collection Techniques and Analyses

Several electronic databases related to education and psychological sciences were searched using a variety of keywords (see Table 1). 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. The literature search identified a population of 307 journal articles, reports, dissertations, or conference papers dating from 1985 to 2009.

Table 1
Search Terms for Electronic Databases

EBSCO	ProQuest	JSTOR	IEEE Explore	H.W. Wilson
(Technology or “Educational Technology”) and Education and Math	(Mathematics or Mathematical Ability or Mathematics Education or Mathematics Teachers or Mathematical Programming) and (Science & Technology Policy or Science and Technology or Technology or Technology Assessment or Technology Education or Technology Standards or Technology Transfer or Technology Acquisition or Technology Adoption or Educational Technology) and (Education or Education & Schools or Education and Schools or Education Discrimination or Education For All Handicapped Children Act 1975-Us or Education History or Education Philosophy)	(((Education and (Math) and (Technology)))	Education and Mathematics and (Technology or "Educational Technology")	Education and (Technology or “Educational Technology”) and "Educational Technology / Use" or "Educational Technology / Teacher Education" and Mathematics or “Mathematics Education”

Analysis Strategies

Studies identified with a quantitative research design were coded as being either randomized or quasi-experimental. We 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.

Summary of Findings

Our pilot results indicate that methodological reporting may limit the ability of many studies to meet the needs of researchers and teachers. Furthermore, we examined the treatment of teacher knowledge as it related to technology implementation in mathematics and found that only half of our pilot sample addressed teacher knowledge at all; of that half, attention was given almost exclusively to pedagogical knowledge, content knowledge, or PCK. We determined from these results that 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.

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