Identifying Evidence-Based, Promising and Emerging Practices That Use Screen-Based Technology to Teach Mathematics in Grades K-8: A Research Synthesis

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Another report is available that covers calculator educational technology practices for mathematics instruction in grades K-12. Both reports share similar literature search and synthesis schemes, and on occasion use the same writing (e.g., introduction, description of strategies) so that they can be stand-alone documents.

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Abstract

Technology is becoming increasingly prevalent in mathematics education; however, it is unclear what effects it has on students, particularly those with special needs. The purpose of this paper is to report on research synthesis work conducted by the Center for Implementing Technology in Education (CITEd), an initiative of the Office of Special Education Programs of the U.S. Department of Education. CITEd staff identified, reviewed, and summarized available evidence about educational technology practices (ETPs) for students with diverse learning needs. The synthesis focuses on mathematics instruction in grades K-8 that used screen-based technology. To develop the synthesis, CITEd staff designed a framework, coding tools, and synthesis scheme; conducted a literature search; coded studies that met review parameters; summarized practices as evidence-based, promising, or emerging depending on the evidence available to support their use; and, determined how the practices reviewed related to the National Council of Teachers of Mathematics (NCTM) content standards. Sixty-one studies were coded for K-8 screen-based technologies and eight ETPs were identified across three NCTM grade bands (i.e., K-2, 3-5, 6-8). Only two of the ETPs were determined to be evidence-based[1]: computer-assisted instruction with tutoring/cooperative learning in grades 3-5 and computer-assisted instruction with screen-based manipulatives in grades 6-8. CITEd's synthesis work in the areas of K-8 screen-based technologies indicates that there are relatively few studies that reflect evidence-based practices and that relatively few research studies exist to test the effects of any particular ETP. Synthesis findings are discussed in terms of needed research for ETPs.

[1] CITEd uses the term "evidence-based" to mean proven effective (i.e., demonstrating that an intervention works), which may differ from a more mainstream definition of evidence-based (i.e., basic research is used to construct an intervention that should but does not always have an impact). The terminology itself is also emerging so the reader should note that our definition may differ from that of others.

Introduction

The use of technology in education is becoming more prevalent; however, it is unclear what effects it has on students, particularly those with special needs. Furthermore, across the education community it is not widely known which technology-based educational practices are supported by research (U.S. Department of Education, National Center for Education Statistics [NCES], 2002). Although progress has been made toward integrating students with disabilities into the general education curriculum, these students continue to be at high risk for academic failure and underperformance in general (Blackorby, Wagner, Cameto, Davies, Levine, Newman, Marder, & Sumi, 2004; Frieden, 2004) and in math in particular (Allsopp, Lovin, Green, & Savage-Davis, 2003; Woodward & Montague, 2002). In the most recent National Assessment for Educational Progress (NAEP), 43% of 4th grade students with disabilities scored below basic level in math. By the time students have completed 8th grade, this number increases to 68% (Neidorf, Binkley, & Stephens, 2006). Given the fundamental importance of math to students' success and livelihood inside and outside of school, such achievement gaps have serious consequences. A number of educators suggest that mathematics instruction can be enhanced by incorporating technology into pedagogy (e.g., Clements, 2000; Hall, 2000; Ruthven & Hennessy, 2002), and although there are a number of publications that synthesize technology use in education (e.g., Burrill, Allison, Breaux, Kastberg, Leatham, & Sanchez, 2002; Ellington, 2003; The McKenzie Group, 2002), it appears that little effort has been made to examine the quality of the research evidence available for any given ETP. To better understand how technology can be used to enhance teaching practices and impact mathematics instruction, it is helpful to identify and synthesize research that addresses the effectiveness of ETPs and to determine how those practices are related to the NCTM content standards[2].

Another pressing need identified by NCTM is the issue of linking research to practice and practice to research (NCTM Research Committee: Heid, Middleton, Larson, Gutstein, Fey, King, Strutchens, & Tunis, 2006). Researchers need to learn from practitioners and accessible research syntheses need to be developed to "inform instructional leaders and policymakers about research perspectives on critical issues of practice" (p. 76) and to help teachers respond to the pressure to "change practice based on research" (p. 83).

To address these concerns, CITEd supports state and local education agencies with developing systems that effectively integrate instructional technology so that all students achieve high educational standards. CITEd provides this support through professional development, technical assistance, promoting communities of practice, and offering web-based resources (see: http://www.citeducation.org). Another service is disseminating information about technology-based teaching practices to the education community. A first step toward providing this service is to identify technology-based teaching approaches that have been subject to empirical investigation (or at least described in the literature), summarize this information in the form of a research synthesis, and distribute information to practitioners. The purpose of this paper is to report on a research synthesis that covers screen-based technologies developed to help teachers of mathematics in K-8 settings.[3]

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[2] NCTM offers a position statement on the use of technology in the learning and teaching of mathematics (http://www.nctm.org/about/position_statements/position_statement_13.htm) and argues that all school math programs should provide access to tools of instructional technology. CITEd reviews the existing research and provides descriptive information to practitioners.

[3] A review of screen-based technologies in grades 9-12 is not ready as of this writing.

Research syntheses on this topic are not a novel idea. In terms of previous synthesis work on screen-based technology, a 1997 review of the educational technology literature (excluding calculators) was conducted by Woodward and Reith and that work contextualized some of the findings described below. Despite the existence of previous work in this area, we recognized the need for a newer synthesis, due in part to the quickly changing nature of educational technology. Indeed, popular hardware and software quickly become obsolete as the ability to develop more innovative technologies continues to evolve. This review updates the earlier review.

Purpose

In sum, this paper endeavors a synthesis of K-8 screen-based technology. Synthesis work on the broad field of educational screen-based technology is nearly a decade old as of this writing. Meanwhile, the types of technology covered by Woodward and Reith (1997) have evolved. This portion of the synthesis involves a review of the screen-based literature to identify ETPs that are evidence-based, promising, or emerging and relate these practices to the NCTM content standards.

General Approach

Our general approach to the synthesis work included:

1. Development of a framework and literature search guide that included parameters for the review, key words, and search strategies
2. Development of a set of coding tools to screen and evaluate the research and a synthesis scheme to evaluate the level of evidence for the ETPs
3. Documentation of findings in practitioner-friendly language and dissemination of resulting products to key consumers (e.g., teachers). Related objectives are to encourage educators to apply technology by giving them concrete examples of how to use it
4. Learn about the status of research in educational technology and identify areas in need of further investigation.

Framework

During the initial stages of the project, CITEd developed a framework that outlined the overall approach, definitions, parameters for the literature review, and literature search processes. One of the initial steps was to define technology, which is easier said than done. A broad definition of technology is “the application of scientific knowledge, or the methods and materials of applied science” (Webster’s Dictionary, 1996, p. 691). It is reasonable to consider some resources that are ubiquitous in U.S. schools, such as chalkboards or textbooks, as forms of technology. We remained interested in technologies that might be thought of as novel and likely to transform pedagogical approaches. This work therefore focused on screen-based (i.e., computer-based) instructional technologies. Given that CITEd’s mission is to inform pedagogical approaches, we focused on what we thought of as *educational technology practices* (ETPs; see Table 1). The most important information to glean from this table is that the review did not focus on technology or educational practices isolated from each other, but rather an interface between the two where the combination is generative (technology transforming practice and practice transforming technology). Finally, CITEd focused on instructional technology (as opposed to assistive technology) because it can be used by all students in the classroom to enhance their educational outcomes. Assistive technology typically benefits only the user of the assistive device (i.e., eyeglasses). Instructional and assistive technologies are not always mutually exclusive however,

so the latter was reviewed to the extent that they are necessary to access the instructional technologies.

In addition to specifying a definition for technology, there is the matter of defining "evidence-based," "promising," and "emerging" practices. Other technical assistance centers have grappled with these definitions (e.g., K-8 Access Center; http://www.k8accesscenter.org) as well as research organizations that have been focused on efforts to figure out how to categorize levels of evidence (e.g., Council for Exceptional Children, 2004). Our definitions, outlined in Table 2, were driven by the availability of original data and the research design used to collect those data.

Other parameters outlined in the framework included: (1) eligible publication years (1985 was the initial cutoff date but was later changed to 1999 because earlier technology had become obsolete), (2) grades (K-8), (3) student population (students with or without disabilities), (4) location (various instructional environments including regular education classrooms, classrooms that included special education students, special education classrooms), and (5) outcome type (academic or behavioral). Academic outcomes include constructs such as scores on standardized tests and curriculum-based measures, and behavioral outcomes include constructs such as motivation and engagement. CITEd also considered teacher outcomes if these were reported in a study, although such information is more ancillary for the purposes of this review.

Literature Search

The literature on educational technology varies widely in purpose, design, and quality. There are also relatively few studies of the effects of screen-based technologies in a mathematics setting and even fewer that utilize quantitative analyses. These factors precluded the use of a traditional meta-analysis. Furthermore, because technology evolves quickly and new approaches may be worth noting even if researchers have not yet been able to investigate their effects, it falls within the mission of CITEd to identify these approaches with a caveat that they have not yet been fully evaluated.

The search started via consultation with experts in educational technology, to identify key words, journals, intervention names, and practices. The keywords identified for K-8 screen-based technologies are located in Table 3 and were used to search EBSCO, ERIC, JSTOR, PsycInfo, PsycArticles, and the AACE digital library. We also reviewed reference sections from meta-analyses and literature reviews that were uncovered as we progressed through the literature search. We were most interested in recent articles (1999 was a cutoff date); however, for screen-based literature we reviewed older articles and we included articles older than 1999 if: (1) they had compelling findings; (2) the technology was still being used; or (3) the studies are not dependent on the version of the technology (e.g., studies about motivation or engagement).

Coding Tools and Synthesis Scheme

CITEd developed a coding tool to evaluate the rigor of the research reviewed. The coding tool for screen-based technologies was developed based on efforts by the What Works Clearinghouse (see: http://www.whatworks.ed.gov/) and the Council for Exceptional Children's indicators of quality research (see: Odom, Brantlinger, Gersten, Horner, Thompson, & Harris, 2004) and it focused on elements such as study design, data collection methods, characteristics of the participants, research goals, and initial determination of whether the practice studied in the article is evidence-based, promising, or emerging. The indicators developed by CEC were both broad enough for our purposes and relatively easy to translate into a coding scheme.

Studies were coded individually by CITEd staff who have extensive research and methodology backgrounds and every fifth article (as well as all articles that were especially complex) was

double-coded for quality control purposes. Coders also participated in initial training to ensure that they had a consistent understanding of CITEd's procedures and terminology. Coders identified articles as level 1 evidence (either for students with or without disabilities), level 2 evidence, or level 3 evidence (see Table 4). Level 1 studies offer original data from rigorous research designs with no design flaws; level 2 studies are based on less rigorous research designs, designs with flaws, or are based on theory; and level 3 studies are not based on research or theory or do not have original data, but do offer professional wisdom or anecdotal evidence. Level 1 studies with positive findings contribute to calling a practice "evidence-based," level 1 studies with mixed findings and level 2 studies contribute to calling a practice "promising," and level 1 studies with negative findings and level 3 studies contribute to calling a practice "emerging."[4]

To synthesize coding results so that statements could be made about the evidence base for ETPs, CITEd developed a scheme (see Figure 1) that synthesized the level of evidence of individual studies into a rating of the evidence available for any given ETP (i.e., evidence-based, promising, or emerging). Note that there are no definitive rules for classifying a practice as evidence-based (Gersten, Fuchs, Compton, Coyne, Greenwood, & Innocenti, 2005). An exception might be a quantitative synthesis of a series of randomized controlled trials that yield an overall, positive effect size with confidence intervals that do not include zero, and satisfy topic-specific criteria for meeting practical significance. On the other side of the coin, no single study on its own can be used to conclude that a practice is evidence-based. Even a high quality, randomized controlled trial will yield an analysis with a possible type 1 error. Complicating matters was the necessity to consider qualitative work and single-case designs. The synthesis scheme presented here allows for the incorporation of these types of designs and our coding utilized CEC's quality indicators (Odom et al., 2004) to enable us to determine their quality and how to incorporate them into our synthesis of ETPs.

Document and Disseminate Findings

K-8 screen-based technology: Synthesis of practices

As noted earlier, our focus for screen-based technologies was on studies published in 1985 or later for students enrolled in grades K-8. A total of 61 articles qualified based on our initial screening criteria and of these 61 articles, 34 were empirical, 7 were descriptive, 7 were literature reviews, 2 were meta-analyses, and 11 were not coded for a variety of reasons (e.g., a deeper read of the article demonstrated that it did not focus on an ETP). The results presented in this section demonstrate the level of evidence (emerging, promising, or evidence-based) for any particular ETP, and present this information by content standard and grade levels as defined by the NCTM (see: http://standards.nctm.org/).

The review yielded eight screen-based ETP categories. Table 5 provides representative examples of each of these ETPs and they are listed below:

- Computer-assisted instruction (CAI) that used hypermedia
- CAI that used games and drill and practice/reinforcement

[4] Although some readers may find this a questionable approach, we made the assumption that developers may be revising the intervention in light of the negative findings. The practice would be emerging until either (a) rigorous research with positive findings has been done at which point it could be called evidence-based or (b) more studies are conducted that show negative findings at which point the practice is deemed not effective.

- Enhanced anchored instruction[5]
- CAI that was more general or unspecified (e.g., did not fit in other defined CAI ETPs)
- CAI combined with tutoring and/or cooperative learning
- CAI that utilized screen-based manipulatives
- CAI with feedback
- Web-based activities

Table 6 provides an overview of the findings for K-8 screen-based ETPs. This table categorizes the coded studies across NCTM standards by NCTM grade bands. It also summarizes the level of evidence available, based on our literature review, for the categories of ETPs outlined in table 5. Topic area categories should be considered general and in many cases studies had content that crossed topic areas—when an article specified that it dealt with multiple content areas, we noted that. A quick review of Table 6 shows that the majority of articles focused on number and operations and that there were more studies available about ETPs for the higher grade bands.

Table 6 reveals that for grades K-2, three of the ETPs are promising and two are emerging. For grades 3-5, one of the ETPs has a level of evidence sufficient to categorize it as evidence-based, two are on the border between evidence-based and promising, two are promising, and two are emerging. Finally, for grades 6-8, one of the ETPs was categorized as evidence-based, two are on the border between evidence-based and promising, three are promising, and two are emerging. A discussion of the evidence-based practices is provided next.

For grades 3-5, a single evidence-based practice—CAI tutoring/cooperative learning—was identified. Supporting this practice were one randomized controlled trial and one quasi-experimental study. The randomized controlled trial (Xin, 1996) studied computer-assisted instruction using cooperative or whole-class learning to examine impacts on 3rd and 4th grade students' (both with and without disabilities) math achievement, attitude, and social relationships. Results showed that 3rd graders who participated in cooperative learning using CAI had higher achievement scores than 3rd graders who participated in the whole-class learning using CAI classrooms. It is important to note that in this RCT, both groups used computer-assisted instruction, so this study demonstrates that CAI plus cooperative learning has an effect; it does not demonstrate that CAI has an effect regardless of the classroom instruction. The quasi-experimental study (Butzin, 2001) compared schools implementing Project CHILD (Computers Helping Instruction and Learning Development; a transformed learning environment where children work in cross-grade clusters and rotate between clusters to receive instruction; Florida State University, 1988) to traditional classrooms. Second through fifth grade regular education students participated for one hour per day over a three-year period and results showed significantly higher academic achievement outcomes (e.g., standardized tests in math) for Project CHILD participants than those in the traditional classes. This study demonstrates that CAI combined with cooperative learning is more effective than a more traditional classroom approach.

For grades 6-8, one practice was identified as evidence-based: CAI screen-based manipulatives. Supporting this practice were two randomized controlled trials conducted by Moreno and her

[5]Enhanced anchored instruction, as described by Bottge and his colleagues, is a way of anchoring the learning of students in problems that seem authentic and meaningful to them, which motivates them and increases their understanding of math. The "anchors" are video clips and the "enhancement" is the hands-on project (e.g., building skateboard ramps) that applies the learning.

colleagues (Moreno & Mayer, 1999; Moreno & Duran, 2004). In the 1999 study, experiment 1, 60 6th graders used a computer-based multimedia program using a number line to help build connections between conceptual and procedural knowledge. Students were taught about adding and subtracting signed numbers using either a symbolic form or using a symbolic, visual, and verbal form over a two-week period to examine the effect of these two teaching styles using a computer-based multimedia game on adding and subtracting signed numbers. Results showed that the multiple representation group outperformed the other group on all dependent variables. In the 2004 study, the same computer-based multimedia program was used with 61 5th and 6th grade students who were taught about adding and subtracting signed integers in either a verbal guidance group or a no verbal guidance group. Posttest scores were significantly higher for students in the guidance group and children with more computer experiences in the guidance group scored better than all other students. As noted for Xin (1996) above, however, both of these studies' treatment and comparison conditions participated in CAI, but what varied was the form in which the CAI was presented. Additionally, only one type of CAI screen-based manipulative was reviewed so it is possible that we are seeing the impact of this practice rather than the impact of this category of practices.

Although other level 1 studies were identified for a number of the ETPs across grade bands (see Table 6) they did not contribute to identifying the practice as evidence-based because their findings were either mixed or there were no effects (thereby contributing to identifying a practice as promising) or negative (thereby contributing to identifying a practice as emerging). Level 1 studies that fall into these categories are footnoted in Table 6.

Conclusions and Discussion

CITEd's synthesis work in the areas of K-8 screen-based technologies indicates that there are relatively few studies that reflect evidence-based practices and that relatively few research studies exist to test the effects of any particular ETP. Furthermore, studies that use rigorous designs to test the effectiveness of ETPs are scarce. Research designs often lack suitable control groups, they use researcher-designed prototypes that are not publicly available that makes replication impossible, and they utilize small sample sizes—a problem that has been salient in studies that have focused on students with disabilities. Instead there is a preponderance of less rigorous methodologies, such as quasi-experimental, case study, and single group pre-post test designs. In addition, while the internal validity problems that are inherent to these designs is considerable, more demanding randomized controlled trials can often times be impractical. In addition to delineating the evidence-based practices captured by our synthesis work, CITEd will provide information about promising and emerging practices to practitioners, but will make it clear that those practices are not as strong. CITEd's work is a first step in the direction of helping educational researchers and educators understand why and how ETPs work.

As mentioned above, CITEd's task for this project is to also provide practitioner-friendly summaries of suggested practices. Such documents can help teachers adapt their curriculum and instruction to make them accessible to all students. The need for evidence-based research in this area is equally important, yet this review of the literature reveals that there is a lack of current research concerning students with special needs and their uses of technology in the area of mathematics. For instance, there is not an extensive body of current research that illustrates practices that assist struggling learners with word problems, representations of mathematical concepts, and applying appropriate problem-solving strategies. Though a majority of the literature reviewed above does not specifically address these issues, CITEd is beginning to take steps towards synthesizing these articles through a special needs lens. An early step in this process was revisiting Woodward and Reith's (1997) literature review for the purposes of

comparing their conclusions of this body of research to those studies reviewed for this current synthesis.

Woodward and Reith (1997) examined studies published between 1980 and 1997 that focused on the uses of technology for students with special needs. Their task was to reveal how teachers used technology in naturalistic settings for the purposes of instruction and assessment. This emphasis, they argue, was a shift from previous reviews of the literature that overemphasized the medium of technology by sacrificing a focus on the embedded pedagogy. The problem with this focus was that previous meta-analyses too often failed to recognize that the pedagogical approach utilized in a computer program often has more of an impact on student learning than the use of technology itself. Second, Woodward and Reith argue that a majority of the studies highlighted in previous literature reviews and meta-analyses were interventions that took place over a very short period of time. This approach is problematic "because students with disabilities can be expected to learn at slower rates, have longer histories of academic failure, and need more intensive instruction than their non-disabled peers, short-term interventions hardly can be expected to produce significant changes" (Okolo et al, 1993, p. 4; quoted in Woodward & Reith, 1997, p. 505). Finally, they point out prior emphases on short-term interventions are also problematic when the focus is on gains in student achievement. Rarely do these studies find that there is a statistically significant change in these students' achievement levels because progression in their learning is often irregular. Short intervention units and research designs simply are not able to capture positive change.

Using these precautions, Woodward and Reith (1997) reviewed studies that emphasized the uses of technology for instruction, assessment, and naturalistic settings for students with special needs. An overall trend that they noticed was the concerted shift from using technology for skill and drill practices to more conceptual approaches to learning. They do, however, point out a few concerns in the design, availability, and uses of technology for students with special needs.

First, the most important problem Woodward and Reith (1997) found was that the technology researched rarely aligned with the specific needs of special needs students: "These studies examine the effects of specific instruction design rather than how these design variables, in conjunction with categorical variables (e.g., average ability, learning disabled, mentally retarded), might suggest one type of technology-based instruction is best suited for students in a particular disability category" (p. 524). From its current review of studies published since 1997, CITEd has found that for the most part these concerns persist. Of the 24 screen-based technology studies reviewed in grades K-8 since 1997, only half included students with special needs in their classroom, and none isolated the specific needs of the individuals in the sample. More often, studies such as Bottge et al. (2003) would mention that the sample included students from "low" and "average" ability. Other studies that did focus on students with special needs (c.f., Wisniewski & Smith, 2002) only pointed out that these students received additional instruction support in a resource room or had Individual Education Plans (IEPs). Though Bottge et al. (2002) used a rigorous research design that included a control group, they were not able to make any specific conclusions about the technology's effectiveness in addressing an individual's learning needs because effects for students with special needs were not isolated.

The second concern Woodward and Reith (1997) point out is the availability of the technology being researched. Too often, they claim, a majority of the technologies examined were prototypes: "While they were robust enough to use in experimental studies, either they were not marketed commercially or they did not achieve sufficient visibility because of the narrowness of the special education commercial market" (Woodward & Reith, 1997, p. 525). Of the sixty-one screen-based studies published since 1985 examined for this synthesis, only ten appear to be

available. For instance, a lot of the video-based instruction Bottge and colleagues (e.g., 2001; 2002; 2003) examined are available online. Reimer and Moyer's (2005) digital manipulatives are also available online. They found the use of this tool effective for students with and without special needs, though they did exclude data from the four autistic students also present in this classroom. It appears that the increased use of the internet is one way researches are making the programs they research accessible for wider audiences; however, many programs remain unavailable as prototypes.

Third, Woodward and Reith (1997) concluded that the research reveals that special education teachers tend to use technology more for motivational than academic purposes. Instead of focusing on technology as a diagnostic tool to facilitate decisions about students' IEPs, special educators were more prone to use computers to get students excited about various academic tasks. The K-8 screen-based articles that CITEd reviewed seem to indicate a shift from this emphasis. That is, those studies in which students with special needs were included as participants focused on academic tasks rather than behavioral (or motivational) outcomes (c.f., Bottge et al., 2001; Fuchs et al., 2002). Two studies published since 1997 that included students with special needs did focus on motivational and academic outcomes, but in these cases the motivational emphasis was either on how "low ability" students worked with their "average ability" peers during cooperative learning activities supported by video learning (Bottge et al., 2004) or compared students' attitudes towards the use of digital manipulatives to how well this tool increased academic achievement (Reimer & Moyer, 2005).

Woodward and Reith's (1997) final concern about the literature up to 1997 was that special education teachers tend to focus too much on the acquisition of basic skills. The articles CITEd has reviewed since then appear to differ. This possible shift towards using technology to facilitate higher-order thinking may be the result of new technologies that promote conceptual learning. Yet, despite this shift, the research is not specific on the benefits for students with special needs.

Another approach is to focus on documented areas of difficulty in learning mathematics for students with special needs and suggest how these new technologies could be of benefit to them. While difficulty with computation and retrieving basic facts has been well researched (Cawley, Parmar, Yan, & Miller, 1998; Cumming & Elkins, 1999; Geary, 2004; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Janssen, De Boeck, Viaene, & Vallaeys, 1999; Jordan & Hanich, 2003), research also indicates that many students struggle with mathematics due to a variety of problems, including limited ability to create and interpret visual representations of mathematical concepts (Booth & Thomas, 2000; Brown & Presmeg, 1993; Geary, 1993; Geary, Hamson, & Hoard, 2000; Hegarty & Kozhevnikov, 1999; van Garderen & Montague, 2003), poor reading, language, and communication skills (Baxter, Woodward, & Olson, 2001; Cawley, Parmar, Foley, Salmon, & Roy, 2001; Fuchs & Fuchs, 2002; Hanich, Jordan, Kaplan, & Dick, 2001; Hegerty, Mayer, & Monk, 1995; Verschaffel, De Corte, & Vierstraete, 1999), and poor problem solving strategies (Lucangeli, Coi, & Bosco, 1997; Ostad, 1998; Pape & Wang, 2003; Xin, Jitendra, & Deatline-Buchman, 2005). It is from this point that CITEd is developing practitioner-friendly documents that outline these evidence-based, promising, and emerging teaching practices that utilize technology as a means for promoting an in-depth understanding of mathematical concepts.

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Table 1. Defining Educational Technology Practices

Curriculum/Subject Area: The general area in which objectives belong.	**Objective:** That which one is trying to teach or influence.	**Educational Practice:** Pedagogical technique believed to promote student learning.	**Technology:** A tool (e.g., pencil, calculator, visual representation software).[6]	**Educational Technology Practice (ETP):**[7] Educational practice combined with technology--synergistic effect on learning.	**Student Outcomes: The measured impact associated with the use of the educational technology practice.**		**Teacher Outcomes/Other Outcomes of Interest**[8]
					Academic	**Behavioral**	
Math	Addition	Drill and Practice	Calculator	Use of a calculator in drill & practice format to help student learn addition	Academic achievement test; teacher grades	Self report of student motivation; observation of on-task behavior	Teacher report of student progress

[6] In an educational context, these tools can be used for instructional or assistive purposes. For the purposes of this review, we will focus on instructional technology but will list assistive applications when we present findings (this effort will be separate from the review phase). Technology is a vastly broad concept but can be classified into various types (e.g., screen-based applications, calculators, etc.), and generally only one given type will be focused on for any single review.

[7] Objective + Educational Practice + Technology = ETP; denotes an interface between education and technology. ETP's, and not technology types, will be the focus of all reviews. If a report describes a technology outside the context of an educational practice, it will not be included in a CITEd review.

[8] CITEd will primarily focus on student-outcomes with reported psychometric properties or that have a 1 to 1 correspondence with the construct of interest (e.g., student grades in math). We will consider other outcomes; for example, we may use the quality of outcome measure as a criterion for classifying a study as a promising, emerging, or evidence-based ETP. To the extent possible, CITEd will also gather other information such as cost, required professional development, type of support available from the developer, etc.

Table 2. Continuum of Definitions: Emerging, Promising, and Evidence-based Practices

Emerging Practices	Promising Practices	Evidence-Based Practices
Includes practices that are not based on research or theory and on which original data have not been collected, but for which anecdotal evidence and professional wisdom exists. These include practices that practitioners have tried and claimed effectiveness. Emerging practices also include new technologies that have not yet been researched.	Includes practices that were developed based on theory or research, but for which an insufficient amount of original data have been collected to determine the effectiveness of the practice. If a study uses a weak design (e.g., one-group pretest posttest) resulting evidence will be categorized as promising. The original data can be for students with or without disabilities. If original data have been collected and a strong design has been used but the study only uses a general education sample, we will note this, but the practice may be considered promising or evidence-based depending on the quality of the research.	Includes practices for which original data have been collected to determine the effectiveness of the practice for students with disabilities. The research utilizes scientifically-based rigorous research designs (i.e., randomized controlled trials, regression discontinuity designs, quasi-experiments, single subject, and qualitative research). Other less rigorous research designs may be categorized here depending on how they compare to CEC quality indicators. Subcategories within this category as well as promising practices may be subdivided later, depending on the type of information found. Evidence-based practices will be divided into two types: practices for students w/ disabilities and practices for students without disabilities that may be used with students w/ disabilities.

Table 3. Search Terms for K-8 Screen-based Technology

Mathematics and K-8 paired with:		
Operations	Functions	Virtual manipulatives
Numerical	Venn diagrams	Interactive tools
Measurement	NCTM standards terminology	Concept instruction
Problem-solving	Visual representation software	Math keys
Manipulations	Graphing drawing programs	CampOS
Algebra	Geometry tools	Tenth planet series
Visualization	Geometry software	Cruncher
Simulation	Dynamic geometry software	CABRI
Set theory	Blocks and tiles	Three dimensional objects
Perceptual software		

Table 4. Evidence Evaluation Captured for Each Study

This study could potentially be categorized as:	
Level 1 evidence (unambiguous findings) for students with disabilities	Includes practices for which original data have been collected to determine the effectiveness of the practice for students with disabilities. The research utilizes scientifically-based rigorous research designs (i.e., randomized controlled trials, regression discontinuity designs and quasi-experiments). If given this rating determine if: • Findings consistently support the ETP for children with disabilities suggesting this is an evidence-based practice • Findings are mixed, suggesting the practice is promising • Findings consistently do not support the ETP, suggesting the practice is emerging
Level 1 evidence (unambiguous findings) for students without disabilities	Includes practices for which original data have been collected to determine the effectiveness of the practice for students without disabilities. The research utilizes scientifically-based rigorous research designs (i.e., randomized controlled trials, regression discontinuity designs and quasi-experiments). If given this rating determine if: • Findings consistently support the ETP for children without disabilities suggesting this is an evidence-based practice • Findings are mixed, suggesting the practice is promising • Findings consistently do not support the ETP, suggesting the practice is emerging
Level 2 evidence (ambiguous findings)	Includes practices that were developed based on theory, less rigorous research designs (e.g., one-group pretest posttest), or designs with serious flaws (e.g., contamination). • Note if the study was descriptive in nature and causal inferences regarding the ETP's effects cannot be made
Level 3 evidence (anecdotal/descriptive)	Includes practices that are not based on research or theory and on which original data have not been collected, but for which anecdotal evidence and professional wisdom exists. These include practices that practitioners have tried and claimed effectiveness. Emerging practices also include new technologies that have not yet been researched.

Table 5. Screen-based ETPs and Representative Examples

ETP	Example
CAI Hypermedia	Students use computer programs and are given screen-based feedback such as screen prompts to read the question carefully to improve problem solving
CAI Games and Drill and Practice/Reinforcement	Students use computerized games like Alien Addition that have embedded drill and practice to improve math achievement
Enhanced Anchored Instruction	Students used the Adventures of Jasper Woodbury Series developed at Vanderbilt University to enhance their problem-solving performance
CAI General or Unspecified	Students are taught on the computer using an unnamed program to determine if their basic mathematics skills can become automatized
CAI Tutoring and/or Cooperative Learning	Students used computer programs in cooperative settings versus competitive and individual learning settings to enhance their mathematics performance
CAI Screen-based Manipulatives	Students are taught on the computer using virtual manipulatives to determine if their procedural and conceptual knowledge can be enhanced
CAI and Feedback	Students are taught using computer-assisted instruction and receive either attributional or neutral feedback to see if type of feedback affects math outcomes
Web-based Activities	Students use online, real-world activities (e.g., banking, house planning) to improve their conceptual mathematical knowledge

Figure 1. CITEd Synthesis Scheme

Assuming no design flaws, positive effects are reported (i.e., the Educational Technology Practice [ETP] group outperforms control groups), and the study design is a:

- Randomized Controlled Trial (RCT)
- Regression Discontinuity (RD)
- Quasi-Experimental Design (QED) with pre-treatment equating of groups, or
- Single Subject

Then it could contribute to making the conclusion that an ETP is evidence-based.

Assuming no design flaws (i.e., findings are unambiguous) and positive effects are reported, if the study design is:

- Qualitative (assuming a casual statement about the effect of an ETP is offered) or
- Correlational (assuming a casual statement about the effect of an ETP is offered; e.g., Structural Equation Modeling)

Then it could contribute to making the conclusion that an ETP is evidence-based or promising.

If the study designs:

- Have flaws that make the findings ambiguous (e.g., QED's that do not do equating)
- Have mixed findings (i.e., both positive and negative findings are noted in such a way that it becomes hard to assess if the ETP is beneficial)
- Are qualitative or correlational, but offer only ancillary causal statements about intervention effects or offer compelling data about intervention delivery/control

Then it could contribute to making the conclusion that an ETP is promising.

If the study designs:

- Are anecdotal reports
- Are purely descriptive studies that do not endeavor to make any causal arguments
- Are empirical studies that show exclusively negative findings (i.e., control/comparison group outperforms groups receiving ETP)

Then it could contribute to making the conclusion that an ETP is emerging.

Evidence-Based Practice

1. **for students with disabilities**
2. **for students without disabilities**

(Note: determination will be made based on sample characteristics and if reporting allows isolating effects by student type)

Promising Practice

Emerging Practice

CITEd will attempt to make summary statements about whether a practice is evidenced-based, promising or emerging. What will determine this ranking is the number of available studies using various designs, as well as whether their findings support the ETP under investigation. The arrows in the above scheme show that, should a study with no design flaws yield positive findings, it will be suggestive the EPT is evidence-based. If the study has design flaws or yields mixed findings, this would suggest the study is promising, and so on. CITEd will consider virtually any study during synthesis work, making it difficult to establish a priori synthesis rules. CITEd will acknowledge the suggestions CEC recently offered for identifying if there is enough evidence to call a practice evidence-based, and will use meta-analysis techniques should the opportunity to arise. Finally, CITEd will carefully examine qualitative and correlational designs studies that endeavor to make causal statements.

Table 6. Summary of Evidence for Screen-based Technologies by Educational Technology Practice, Mathematics Topic, and Grade Band

Educational Technology Practice[9]	Evidence Synthesis	Number and Operations	Algebra	Geometry	Measurement	Data Analysis & Probability	Multiple Topics
Grades K-2							
CAI Hypermedia	Emerging	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1				Same study addressed two content standards
CAI Games/Drill and Practice/Reinforcement	Promising	Level 1=2[10] Level 2=1 Level 3=4					
CAI General/Unspecified	Promising	Level 1=2[11] Level 2=1 Level 3=0					
CAI Tutoring/Cooperative Learning	Promising	Level 1=1[12] Level 2=0 Level 3=0					
Web-based activities	Emerging	Level 1=0 Level 2=0 Level 3=1					

[9] ETPs not listed in the table did not contain any reviewed studies

[10] Findings for one study were mixed and positive and for the other study there were no effects which downgrades the studies to contributing to a promising practice

[11] Findings were mixed and positive which downgrades the studies to contributing to a promising practice

[12] Findings were positive but one study is not sufficient to call a practice evidence-based

Educational Technology Practice[13]	Evidence Synthesis	Number and Operations	Algebra	Geometry	Measurement	Data Analysis & Probability	Multiple Topics
Grades 3-5							
CAI Hypermedia	Emerging	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1				Same study addressed two content standards
CAI Games/Drill and Practice/Reinforcement	Evidence-based/promising	Level 1=5[14] Level 2=0 Level 3=2					
Enhanced Anchored Instruction	Promising	Level 1=0 Level 2=1 Level 3=0					
CAI General/Unspecified	Promising	Level 1=5[15] Level 2=2 Level 3=0	Level 1=1 Level 2=0 Level 3=0				One level 1 study addressed two content standards
CAI Tutoring/Cooperative Learning	Evidence-based	Level 1=2 Level 2=0 Level 3=0					
CAI Screen-based manipulatives	Evidence-based/promising	Level 1=1[16] Level 2=1 Level 3=2					
Web-based activities	Emerging	Level 1=0 Level 2=0 Level 3=1					

[13] ETPs not listed in the table did not contain any reviewed studies

[14] Findings for one study were mixed, for another there were no effects, and for a third both groups showed an increase in performance which downgrades the studies to contributing to a promising practice

[15] Findings from two studies were mixed and positive, findings from another study were mixed, findings from a 4th study showed increases in both groups, and findings from a 5th study showed no effects which downgrades the studies to contributing to a promising practice

[16] Findings were positive but one study is not sufficient to call a practice evidence-based

Educational Technology Practice[17]	Evidence Synthesis	Number and Operations	Algebra	Geometry	Measurement	Data Analysis & Probability	Multiple Topics
Grades 6-8							
CAI Hypermedia	Emerging	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1				Same study addressed two content standards
CAI Games/Drill and Practice/Reinforcement	Evidence-based/promising	Level 1=2[18] Level 2=2 Level 3=1	Level 1=0 Level 2=1 Level 3=0	Level 1=1[19] Level 2=0 Level 3=0			One level 2 study addressed two content standards
Enhanced Anchored Instruction	Evidence-based/promising	Level 1=3[20] Level 2=2 Level 3=0	Level 1=3 Level 2=1 Level 3=0		Level 1=2 Level 2=1 Level 3=0		Two level 1 studies counted in two content standards; one level 1 study counted in three content standards
CAI General/Unspecified	Promising	Level 1=3[21] Level 2=1 Level 3=0	Level 1=0 Level 2=1 Level 3=0				
CAI Tutoring/Cooperative Learning	Promising	Level 1=1[22] Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1	Level 1=0 Level 2=0 Level 3=1	One level 3 study counted in all content standards
CAI Screen-based manipulatives	Evidence-based	Level 1=2 Level 2=0 Level 3=0					

[17] ETPs not listed in the table did not contain any reviewed studies

[18] Findings were positive for one of the studies but one study is not sufficient to call a practice evidence-based

[19] There were no effects for this study which downgrades it to contributing to a promising practice

[20] The four level 1 studies represented across content standards all showed mixed and positive findings which downgrades these studies to contributing to a promising practice

[21] No effects for two studies and mixed effects for a 3rd study which downgrades these studies to contributing to a promising practice

[22] Findings were positive but one study is not sufficient to call a practice evidence-based

17	Evidence Synthesis	Number and Operations	Algebra	Geometry	Measurement	Data Analysis & Probability	Multiple Topics
Grades 6-8 (cont'd)							
CAI + Feedback	Promising	Level 1=1[23] Level 2=0 Level 3=0					
Web-based activities	Emerging	Level 1=0 Level 2=0 Level 3=1					

[23] No effects for this study which downgrades it to contributing to a promising practice