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Analysis of studies of the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities

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ABSTRACT

The purpose of this study was to conduct a meta-study of computer-assisted instruction (CAI) studies in mathematics for students with learning disabilities (LD) focusing on examining the effects of CAI on the mathematics performance of students with LD. This study examined a total of 11 mathematics CAI studies, which met the study selection criterion, for students with LD at the elementary and secondary levels and analyzed them in terms of their comparability and effect sizes. Overall, this study found that those CAI studies did not show conclusive effectiveness with relatively large effect sizes. The methodological problems in the CAI studies limit an accurate validation of the CAI's effectiveness. Implications for future mathematics CAI studies were discussed.

1. Introduction

Ginsburg, Klein, and Starkey (1998) emphasized, "we live in a society in which mathematical knowledge is commonly portrayed as vitally important for economic success, and indeed for everyday functioning" (p. 402). Given such importance of mathematics in our society, many researchers in the field of special education have made efforts to facilitate the mathematics performance of students with learning disabilities (LD) over the past few decades (Fuchs et al., 2008; Gersten, Jordan, & Flojo, 2005). According to the definition of LD, students with LD do not achieve adequately for their age or grade level standards in various academic skills, such as listing and reading comprehension, basic reading skills, and mathematics calculation and problem solving (Fletcher, Lyon, Fuchs, & Barnes, 2007). Evidences have demonstrated that a majority of students with LD have serious difficulties learning mathematics with much lower mathematics achievement levels than their same-age peers without LD (Bryant, 2005; Fuchs et al., 2008). For example, the mathematical achievement of 8- and 9-year-old students with LD was comparable to that of 6-year-olds (Cawley & Miller, 1989). At the secondary level, the performance of 16- and 17-year-old students with LD was equivalent to that of 10-year-olds (Cawley & Miller, 1989). Even in basic mathematics skills for daily life, such as telling time and counting money, students with LD did not have the same competent level of their same-age peers without LD (Bransford, Hasselbring, Barron, Littlefield, & Goin, 1989).

Despite such deficits of students with LD in mathematics performance, the international trend toward inclusion has allowed students with LD to receive most of their mathematics instruction in general education classrooms and same mathematics curriculums that their peers without LD received (Lock, 1996). Unfortunately, there has been evidence (Cawley & Miller, 1989; Cawley, Parmar, Yan, & Miller, 1998) to demonstrate that students with LD cannot fully benefit from mathematics instruction and curriculum in general education classrooms (Salend, 1994). Commonly, students with LD struggle with too rapid pacing of introducing new mathematics concepts, and insufficient examples, explanations, practice, and review in general education classrooms (Salend, 1994). In fact, teachers are willing to provide additional instructional and adapted materials to facilitate the successful learning of students with LD in their classrooms (Busch, Pederson, Espin, & Weissenburger, 2001; Schumm et al., 1995). Due to increasing number of students in classroom and limited instructional time and resources, however, teachers are often confronted with the challenge of providing individualized and additional supports to meet the instructional needs of students with LD (Busch et al., 2001; Schumm et al., 1995).

To address those challenges confronted by teachers, technology has been recommended by many researchers with high expectations for its potentiality and flexibility (Woodward & Carnine, 1993). It has been argued that technology can adapt and individualize mathematics instruction for students with special needs (Bryant & Bryant, 1998; National Council of Teachers of Mathematics

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[NCTM], 2000). Especially for students with LD, technology can offer a variety of individualized mathematics instructions to meet their special learning characteristics and to ensure their successful mathematics achievement in general education settings (Hasselbring, Goin, & Bransford, 1988; Symington & Stranger, 2000). As the quality and availability of technology has dramatically increased in the past decade, researchers and educators have made efforts to apply technology to the mathematics curriculum for students with LD to enhance their mathematics performance (Anderson-Inman, Knox-Quinn, & Horney, 1996; Ferretti & Okolo, 1996; Raskind & Higgins, 1998; Torgesen & Barker, 1995). As the most typical application of technology in education, computer-assisted instruction (CAI), defined as the use of a computer to provide instructional contents, has been suggested as a promising instructional method to facilitate the mathematics learning of students with LD (Aydin, 2005; Okolo, 1992a; Poplin, 1995). Therefore, a large body of research involving CAI in mathematics for students with LD has been increasingly emerged since the 1980s (Gleason, Carnine, & Boriero, 1990; Lewis, 1998).

Given the growing number of mathematics CAI studies for students with LD, several meta-studies including literature reviews, syntheses, and meta-analyses (Kroesbergen & Van Luit, 2003; Mastropieri, Scruggs, & Shiah, 1991; Miller, Butler, & Lee, 1998; Swanson, Hoskyn, & Lee, 1999) in the field of special education have documented the overall effects of CAI on the mathematics performance of students with LD. However, several limitations regarding a systematic analysis of the effectiveness of CAI in mathematics for students with LD are found in these meta-studies. Those limitations can be summarized as follows:

- First, the previous meta-studies focused on all mathematics intervention studies, including mathematics CAI studies, for students with special needs (Kroesbergen & Van Luit, 2003) or LD (Mastropieri et al., 1991; Miller et al., 1998), or all CAI studies in all subject areas, including reading, writing, spelling, mathematics, and social studies, for students with LD (Swanson et al., 1999). Therefore, an in-depth analysis of each CAI study in mathematics for students with LD was limited. Especially, two meta-analyses (Kroesbergen & Van Luit, 2003; Swanson et al., 1999) examined the effectiveness of CAI in terms of effect sizes. As mentioned before, these meta-analyses, however, did not solely focus on CAI studies in mathematics for students with LD. Therefore, the magnitude of effectiveness for each mathematics CAI study for students with LD was not fully analyzed.
- Second, the most recent meta-analysis (Kroesbergen & Van Luit, 2003) included mathematics CAI studies published before 2000, it is necessary to update literature including recent mathematics CAI studies, published after 2000, for students with LD.
- Third, according to Clark (1983), the instructional principles and features (e.g., controlling task difficulty, and providing corrective feedback and strategy) embedded in CAI programs are critical factors closely related to students' positive academic outcomes during CAI. Despite the importance of instructional features of CAI programs, the previous meta-studies did not fully analyze them. Therefore, the question of which instructional features embedded in CAI programs were critical to facilitate the mathematics performance of students with LD was not clearly answered.

Given these limitations of earlier meta-studies on our topic, we had motivation for our study to examine the findings of selected set of CAI studies on the mathematics performance of students with LD at the elementary and secondary levels, with particular attention to the instructional features inherent in CAI programs. More importantly, this study calculated the effect size for each CAI study to analyze the magnitude of effectiveness of CAI for the mathematics performance of students with LD. The following question guided this study:

What are the effects of CAI on the mathematics performance of students with LD at the elementary and secondary levels?

In analyzing the results of mathematics CAI studies for students with LD, this study is able to make a significant contribution to the field of education and educational technology in several ways. First, this study provides the information on effectiveness, strengths, and weaknesses of mathematics CAI to teachers and researchers who are interested in improving the mathematics performance of students with LD using mathematics CAI. Second, the review of the instructional features of mathematics CAI programs in this study guides future researchers and software programmers who are interested in designing and developing CAI programs for students with LD. Lastly, this study's findings on the methodological limitations in the previous mathematics CAI studies gives caution to future CAI researchers who plan to conduct to mathematics CAI research for students with LD at elementary and secondary levels.

2. Methods

2.1. Study selection criteria

For the purposes of this study, computer searches of *Psyinfo*, *Education Full Text*, *Academic Search Premier*, *Google Scholar*, and *Educational Resources Information Center (ERIC)* databases were conducted. All databases were searched from January 1980 to September 2008. This 28-year period was selected because studies of computer use in special education were initiated in the early 1980s (Woodward & Carnine, 1993). The keywords used for this study were 'mathematics,' 'computer-based instruction,' 'CBI,' 'computer-assisted instruction,' 'CAI,' 'technology,' and 'learning disabilities.' Grant and conference papers, dissertations, newsletter articles, and other unpublished documents were not searched to examine experimental and reliable CAI data only. By a manual search, the recent volumes, from January 2005 to September 2008, of well-known seven journals where most of the empirical studies were published in special education were reviewed to find studies which were not found through the computer search. Those journals included *British Journal of Learning Disabilities, Journal of Learning Disabilities, British Journal of Special Education,* and *Learning Disability Quarterly*. Additionally, the recent volumes, from January 2005 to September 2008, of three journals, which were primarily related to technology in special education, were manually checked. Those journals were *Journal of Special Education Technology, Technology and Disability,* and *Special Education Technology Practice*. The reference lists from earlier meta-studies including literature review articles, research syntheses, and meta-analyses (e.g., Fitzgerald & Koury, 1996; Hasselbring & Glaser, 2000; Kolich, 1985; Kroesbergen & Van Luit, 2003; Maccini, Gagnon, & Hughes, 2002; Majsterek & Wilson, 1989; Mastropieri et al., 1991; Miller et al., 1998; Woodward & Rieth, 1997; Xin & Jitendra, 1999) in special education were also reviewed to identify additional studies. This initial search resulted in 23 studies related to CAI in mathematics for students with disabilities. The specific criteria for selecting appropriate CAI studies for this study were developed as follows: