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A Retrospective Analysis of Technological Advancements in Special Education

SUMMARY. This article investigates the impact that technology and computers have had over the past 20 years in the field of special education. A review of the literature on technology and computers was conducted in the flagship journals in the areas of learning disabilities, mental retardation, deaf/hard of hearing, and gifted/talented. The analysis yielded a va-

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riety of trends that were specific to each subfield. Findings were compared to the general literature in technology and revealed that the literature in each field reflected the general advances in, and availability of, technology over time.

KEYWORDS. Technology, computers, special education, learning disabilities, mental retardation, deaf, hard of hearing, gifted, talented

INTRODUCTION

Very few innovations have matched the growth of computer use in all areas of education, but the overwhelming changes in technology use in all areas of special education warrant attention. The mid 1970s were especially exciting times for technology innovation. Apple computers released the Apple II series, and computer-based instruction (CBI) emerged as a viable alternative in education. By 1983, IBM was the sole personal computer (PC) manufacturer, and microcomputers gained attention in our society as *Time* magazine named the computer as "Man of the Year" (Blackhurst & Edyburn, 2000).

The growing popularity of microcomputers also became prevalent in the field of special education. A series of federal laws were put into place to support and assure that technology and related services were provided to individuals with disabilities (see Assistive Technology Act, Individuals with Disabilities Education Act, and Americans with Disabilities Act). Blackhurst and Edyburn (2000), however, remind us that technology has played a significant role in the lives of individuals with disabilities, even prior to the innovations seen during the 20th century.

While the infusion of technology into special education programs predates even the invention of the microcomputer, research on the impact of technology is scant in the literature prior to the 1980s. During this early stage of interest in technology as an educational innovation, the main thrust of research was dedicated to how available technologies could be used to address the individual needs of students. Software programs were designed primarily for use as tutorials, to encourage drill and practice, or as enrichment in the form of games and simulations. From the beginning, there was a differentiation in the use of technology, which depended heavily on the exceptionality for which it was used. For example, in the areas that deal with students with disabilities, technology was viewed primarily as assistive, concentrating on facilitating student ability to communicate and promoting academic success. On the other end of the

spectrum, technology used with gifted students tended to focus on expanding the users' experience with the content and using software that promoted active engagement, higher order thinking, and abstract reasoning.

Today, many educators view technology as a vehicle for promoting thinking and as a delivery system that allows students to reach beyond the confines of more traditional learning experiences. Even the use of assistive technology for students with special needs has changed and is used to open up exciting possibilities for learning. As a differentiation tool, technology allows students of all ability levels to work within their own style preferences and readiness levels. For example, students who use the Internet as a research tool will find a wide variety of available resources. Teachers may allow some students who have the ability to think abstractly and problem-solve to freely search their topic while others are given guidance toward specific resources that fit the topic at hand. Technology, such as the Internet, can provide yet other students the ability to communicate with others in a bias-free environment.

The purpose of this article, therefore, is to identify the impact that computers and technology have had on the field of special education and specifically to show the broadening use of technology over time in the lives of individuals with exceptionalities. Throughout this article, unless otherwise noted, the term *technology* will be used to include all aspects of instructional technology and assistive technology, including but not limited to computers.

For this retrospective look at technology in special education, we determined to look back to the year 1981, which approximately estimates when computers were first introduced in schools. A literature search was conducted by each of the authors in her/his area of expertise using both online and hand-search methods. Each author examined the flagship journal(s) in her/his area using the key terms *technology, assistive technology,* and *computers.* The data were analyzed using a naturalistic approach that allows for the emergence of themes (Lincoln & Guba, 1985). The emerging themes were then cross-checked by the authors to identify overall trends in the field. The results are presented by subfield, and a review of the overall trends can be found in the conclusion. The general headings, which match the subfields investigated, include: Learning Disabilities, Mental Retardation, Deaf/Hard of Hearing, Gifted and Talented.

LEARNING DISABILITIES

The research on using technology for students with learning disabilities reflects the complex instructional and assessment nature of the field of learning disabilities. A thorough investigation of three flagship journals–*Journal of Learning Disabilities, Journal of Special Education Technology,* and *Exceptional Children*–revealed several recurring themes: (a) computer-assisted instruction (CAI), (b) multimedia, and (c) tools for learning.

Historical Trends

Computer technology in the early 1980s for students with learning disabilities was comprised primarily of instruction commonly referred to as *computer-assisted instruction* (CAI). Such instruction generally consisted of drill-and-practice lessons to build specific skills. Researchers and educators implemented CAI to provide individualized instruction to students with learning disabilities (Bahr & Reith, 1989; McDermott & Watkins, 1983; Woodward, Carnine, Gerten, Gleason, Johnson, & Collins, 1986). Computers used in this capacity were viewed as playing the role of the tutor (Woodward, Gallagher, & Reith, 2001). This role came about as the computer was identified as an extremely efficient medium for delivering various levels of academic instruction, allowing students to work at their own pace and skill level and providing them with immediate feedback. In addition to tutorial software, drill-and-practice software provided learners with a multitude of opportunities to practice a single skill already taught. Computer-assisted technology seemed a natural fit into the traditional direct instruction curriculum that was typically found in special education classrooms.

As classroom instruction began to change, a new dimension to CAI was investigated. Researchers began to look at instructional design variables for effective instruction for students with learning disabilities (Woodward & Cuban, 2001). In the early 1990s researchers (e.g., Anderson-Inman, 1990-91; Boone & Higgins, 1993) developed computer-assisted instruction that engaged the learner through hypermedia. Higgins, Boone, and Lovitt (1996) investigated the use of hypermedia study guides and information retention with students identified as having learning disabilities and students receiving remedial services. Findings revealed that hypermedia study guides were viable educational tools. A three-year, school-based research study conducted by Boone and Higgins (1993) investigated the use of hypermedia support and basal readers. This study confirmed the effectiveness and use of hypermedia software for students in special education who participate in the general education curriculum.

Although the body of research in the area of hypermedia-based instruction is relatively small and could benefit from further investigation, instructional benefits of hypermedia and its use by students with learning disabilities have been reported at the elementary, middle, and high school grade levels (Anderson-Inman, 1990-91; Boone & Higgins, 1993; Higgins & Boone, 1990, 1991, 1993; Lewis, 2000; MacArthur & Haynes, 1995).

Multimedia

As technology began to advance in the late 1980s and early 1990s, researchers working in the field of learning disabilities began to investigate the power of graphics, and multimedia for learning. Multimedia–a combination of graphics, video, animations, pictures, and sound–provides diverse learning instruc-

tion and has been used for years in the classroom. Multimedia instruction provides the learner with ample opportunities to become interactive in the learning process.

The Cognition and Technology Group at Vanderbilt (CTGV) completed extensive research on the application of multimedia instruction. The major focus of their work involved the use of videodisc environments. Such situated environments provide rich opportunities and realistic contexts that encourage the active construction of knowledge by learners (Cognition and Technology Group at Vanderbilt, 1993).

As a result of advancing technology, more and more multimedia applications have become computer-based, making a shift from a receptive mode to a more interactive mode. Research conducted by Daiute and Morse (1994) involved the use of multimedia writing tools for students with disabilities. Findings concluded that students could experience writing success through the power of multimedia. Multimedia was found to be one way teachers can help children connect their specific perspectives and ways of expressing themselves to a common curriculum.

Multimedia makes important information more obvious (Najjar, 1996). Research supports the positive benefits of multimedia instruction for students with learning disabilities or those who may have limited prior knowledge in a particular academic area. Multimedia learning materials engage the learner in multiple representations of content to be learned.

Tutor versus Tool Metaphor

As technology became more common in our classrooms, educators and researchers were discovering the role of technology in the instructional process. The role of computers began to shift from "tutor to tool" (Woodward & Cuban, 2001). Technology had shifted from providing instruction to providing support for completing learning tasks and processes. Word processors, word prediction, speech recognition, spell checkers, text-to-speech programs, graphic organizers, and online resources provided students with learning disabilities opportunities to strengthen their academic weaknesses and complete a desired learning task with hope that academic growth would be achieved.

Word processing. As early as 1989, educators were discussing the liberating effects experienced by students with reading difficulties when basic word-processing applications were integrated into their language experience lessons (Sharp, 1989). Word processing and spell checkers have long been recognized as valuable tools in improving student writing, and those with learning disabilities especially benefit by being afforded the opportunity to edit easily and produce a highly legible finished product (Graham & MacArthur, 1998; Lewis, Graves, Ashton, & Kieley, 1998; MacArthur, 1996, 1998, 1999; MacArthur & Graham, 1987; MacArthur, Graham, & Schwartz, 1991; Outhred, 1989). Such a product would have been difficult to produce by these students

without accessibility to word-processing applications (Woodward & Rieth, 1997).

Word prediction. Word prediction software provides the student with learning disabilities a tool to make the writing process more approachable. Such programs were found to enhance the text-entry speed of students with learning disabilities by allowing the student to simply recognize a word instead of spelling it out by individual letters (Lewis et al., 1998; MacArthur, 1999). Additional research conducted by MacArthur (1999) revealed that word prediction can make a substantial difference for those individuals with severe writing problems that interfere with the readability of their writing.

Speech recognition. The advancement/improvement of speech recognition technology is changing rapidly. De La Paz (1999) states that "in anticipation to such technological advancements, a small but growing group of researchers has conducted research during the past 10 years to determine how this technology might best be used with persons with learning and writing problems" (p. 174).

Speech recognition has been researched both as assistive technology to overcome difficulties in writing and as a tool to build remedial skills in reading and spelling (Elkind, Black, & Murray, 1996; Higgins & Raskind, 1995; Higgins & Zvi, 1995). Results were encouraging; students exhibited significant improvement in writing composition using speech recognition as compared to writing with word processing, or pencil and paper, or dictation to another person (Higgins & Raskind, 2000). In addition, the use of speech recognition to build remedial skills demonstrated an increase in word recognition, speed, accuracy, and reading comprehension.

As we investigate the effectiveness of speech recognition and other computer technologies for students with learning disabilities, it is essential to not only investigate the role that technology plays but also the strategies and metacognitive skills that are necessary to engage the individual in the specific learning tasks. With a better understanding of these components we can assist students in learning for understanding and provide them with the tools to create knowledge that is useful (Hasselbring, 2001).

MENTAL RETARDATION

A review of the flagship journals in mental retardation resulted in the identification of three general themes: historical trends, technology as a tool, and barriers. Each of these categories will be discussed according to specific themes revealed as a result of the review.

Historical Trends

Equal access to all aspects of life has always been an issue for individuals with mental retardation. Access for these individuals has relied heavily on the

use of adaptive devices and technologies. Prior to the passage of P.L. 94-142 and the deinstitutionalization of individuals with mental retardation in the 1980s, most devices used by individuals with metal retardation would be considered "low tech." Low tech devices–described as simple, passive, and having few moving parts–include adaptive switches, cell systems, communication boards, adaptive books, adaptive eating utensils, tactile enhancement tools, etc. (Angelo, 1995; Mann & Lane, 1995; Parette, 1997). P.L. 94-142 and deinstitutionalization brought individuals with mental retardation into the community and public schools by mandating a free and appropriate education. To meet the learning needs of these students, the focus of technology moved from "low tech" to "high tech" devices. High tech devices, described as being more complex, usually incorporating sophisticated electronic components, include augmentative and alternative communication devices, modified or alternative keyboards, Braille printers and text-to-speech devices, and computers for educational tasks (Huntinger, 1996; Inge & Shepherd, 1995; Parette, 1997). It was ultimately shown that technology, as a teaching tool, would help give individuals with mental retardation equal access to the appropriate education they deserved.

Technology as a Tool

Technology as a teaching tool immediately, profoundly, and positively impacted the education of individuals with mental retardation. The use of assistive technology devices for individuals with mental retardation was shown by Wehmeyer (1998) to increase self-determination, independence, and integration skill. In addition, assistive devices allowed for "positive changes in inter- and intrapersonal relationships, sensory abilities and cognitive capabilities, communication skills, motor performance, self-maintenance, leisure, and productivity" (Parette, 1997, p. 268).

While many of the "low tech" and "high tech" assistive technology devices have greatly increased access to the learning environment for individuals with mental retardation, the introduction of the computer as a teaching tool, and subsequent supporting software, can be viewed as the greatest agent of change in relation to both the curricula taught and the teaching methods employed for individuals with mental retardation. Technology, in the form of interactive computers and software, is now being used to enhance the learning of these individuals by providing alternative pathways to acquiring knowledge and skills.

Initial studies in the 1980s and early 1990s identified computers, specifically computer-assisted instruction, as an effective teaching tool to support the acquisition of basic learning skills (Chen & Bernard-Opitz, 1993; Iacona & Miller, 1989; Thomas, 1981). More currently, the trend in research and in the special education literature has become the use of technology to enhance and/or open new avenues of learning and communication for individuals with

mental retardation. Technology is now being used to develop functional curricula to better teach academic courses in schools and to help better prepare individuals with mental retardation for the transition to life after school.

Preparing individuals with mental retardation for the workplace through the use of technology has been an emerging theme in special education literature. Morgan, Gerity, and Ellerd (2000) used video and CD-ROM technology to help individuals with severe disabilities establish job preferences. Kyhl, Alper, and Sinclair (1999) used videotaped instruction to aid in job acquisition, and Furniss et al. (1999) looked at the use of palmtop-based devices to aid individuals with severe intellectual disabilities in the workplace setting.

A second theme evident in the literature is the use of assistive technology devices as a means of opening avenues of communication for individuals with mental retardation. Voice output communication aids, used to produce synthetic or digitized speech, have been used successfully with individuals with autism and related disabilities (Beukelman & Mirenda, 1992; Mirenda, Wild, & Carson, 2000; Schepis, Reid, Behrmann, & Sutton, 1998). Although viewed as controversial in the field of education, facilitated communication, the use of keyboards or alphabet boards, has been used as a means of communication for individuals with severe mental retardation, autism, or other related disorders (Sheehan & Matuozzi, 1996; Salomon-Weiss, Wagner, & Bauman, 1996).

A third emerging theme in special education literature is the use of a variety of technology to aid individuals with mental retardation in the acquisition of lifeskills. Developing and maintaining meaningful relationships have historically been problematic for these individuals. Renbald (1999) used technology to aid in the development of social networks of individuals with mental retardation. Browning and White (1986) used an interactive video-based curriculum to teach life-enhancement skills to these individuals.

Lastly, technology is now being used to help individuals with mental retardation produce work in the classroom for ongoing assessment. Denham and Lahm (2001) outlined how, through the use of assistive technologies, students with moderate to severe disabilities construct alternative portfolios of their work. Through the use of adaptive tools such as IntelliKeys keyboards and Overlay Maker, students were able to construct portfolios of their year-long work. These tools have allowed students with mental retardation to produce products similar to their nondisabled peers.

The Future of Assistive Technology–Overcoming Barriers

The future use of assistive technology for students with mental retardation does not necessarily lie in the development and implementation of new technologies but in the proper and full implementation of current technologies. The Association for Retarded Citizens (The Arc), a national advocacy organization that represents individuals with mental retardation and their families, has repeatedly voiced concerns related to access to technology for people with men-

tal retardation. Wehmeyer (1999), summarizing the position of The Arc stated, "It appears that, for a variety of reasons, assistive technology devices remain largely underutilized by people with mental retardation" (p. 49). Studies by Wehmeyer (1999) and Derer, Polsgrove, and Rieth (1996) support The Arc's view that many appropriate and helpful assistive technology devices are being underutilized by these individuals.

Researchers have identified a number of issues that help to explain the current underutilization of assistive technology devices by individuals with mental retardation. Issues include the abandonment of technology (Parette, 1997), the cost of purchasing devices (Parette, 1997; Walker, 1991; Wehmeyer, 1999), the lack of information about what technologies are available and their use (Wehmeyer, 1999, 1998), the identification of appropriate technology features (Batavia & Hammer, 1990; Parette, 1997; Schere, 1993), the lack of assistive technology devices that can be used by individuals with mild to severe cognitive disabilities (Wehmeyer, 1998), and, lastly, the development of devices that are too complex (Perlman, 1993; Wehmeyer, 1998).

Access to all aspects of what society has to offer has always been at the forefront of issues for individuals with mental retardation. Technology as a tool, whether "low tech" or "high tech," has greatly increased access to public education for individuals with mental retardation. The future development of technologies is sure to offer an even greater level of access to the community and education as long as current and future barriers to the use of technologies for individuals with mental retardation are addressed.

DEAF/HARD OF HEARING

Traditional uses of technology have provided tremendous support to individuals with a hearing loss. Advances in computer use, however, have also provided challenges to persons with a hearing loss because computers are inherently an auditory-visual medium (Strepp, 1994). Although this visual component has allowed for presenting visual communication, the literature available from technology and special education journals has focused on instruction with technology and has dealt with the focus of the development and use of technology to work with or around the hearing loss. The two main journals in the area of deafness *(American Annals of the Deaf* and *Volta Review)* have even had special theme issues on technology, in some cases more than once, over the past 20 years. *American Annals of the Deaf* has included a technology issue section in each journal published, further highlighting the importance of technology to the field.

For individuals who are deaf/hard of hearing the overarching focus of the literature has been around classroom instruction, as well as specific technology to assist with the hearing loss or to facilitate the auditory educational environment. The past 20 years of professional journals have demonstrated a

parallel development and distribution of each of these notions over time. These specific research issues have included closed captioning, real-time captioning, text telephones (TTY/TDD), FM systems, and mechanisms related to speech and speechreading.

Historical Trends

Even with the auditory quandary that classroom computers pose, they have also presented a new visual access for learning that was capitalized early on to assist with instruction and with individuals who are deaf/hard of hearing. As early as 1981 the *Volta Review* published an entire issue on learning technology for individuals who are hearing impaired that presented specific "tools" to support learning for individuals with a hearing loss (i.e., closed captioning, real-time captioning, and speech programs) as well as instructional technology for language acquisition and language learning (Withrow, 1981). Twenty years later the issues remain the same.

A number of surveys have attempted to identify the technology schools possess and the needs for such technology (Corbett & Micheaux, 1996; Deninger, 1985; Harding & Tidball, 1982; Harkins, Loeterman, Lam, & Korres, 1996; Pillai, 1999; Rose & Waldron, 1984). Corbett and Micheaux (1996) identified a few residential schools for individuals who are deaf that have clearly put a considerable amount of money into hardware, software, and connections for instructional technology, to improve educational and social programs. In other classrooms across the country representing more public school programs, not only was the need for more equipment identified but also teacher training and time devoted to instructional technology (Harkins et al., 1996; Pillai, 1999). A current survey of teacher education programs for the individuals who are deaf/hard of hearing identified the continuous need for the integration of technology in the classroom and teacher education (Roberson, 2001).

Instruction and Learning

Early in the history of technology use, special computer programs for the individuals who are deaf/hard of hearing were designed and used in residential settings, offering drill and practice primarily to work on language development, later moving into speech development and other curricular areas (Richardson, 1981). There was a call for instructional applications of computers to broaden the diversity of instructional programs for students who are deaf/hard of hearing (Stuckless & Carroll, 1994).

The literature has described ways in which integrating a variety of media will assist in instruction (Hasselbring, 1994) and language learning of individuals who are deaf/hard of hearing (Volterra, Pace, Pennacchi, & Corazza, 1995). In one study word prediction technology with individuals who are

deaf/hard of hearing was shown to improve word fluency (Laine & Follansbee, 1994).

Specific technologies for instruction and learning include a focus on e-mail, videodisc, World Wide Web (WWW), virtual reality, and hypermedia. E-mail used with individuals who are deaf/hard of hearing and hearing students to communicate curriculum through written communication has been very successful. Since oral communication can be difficult for some individuals who are deaf/hard of hearing, this collaborative writing tool assists students with a hearing loss in this communication process (Weiserbs, 2000).

Videodisc technology has been used to create interactive instructional programs to successfully teach speechreading (Slike, Thornton, Hobbis, Kokoska, & Job, 1995). A unique program was designed and tested targeting three-dimensional virtual reality programs with students who are deaf/hard of hearing. The study found that these programs could improve flexible thinking. Additional learning opportunities were provided through the use of virtual reality (Passig & Eden, 2000). Clymer and McKee (1997) described a survey expressing the high rate of use of the WWW with students who are deaf/hard of hearing. In dealing with the auditory component of computer technology, hypermedia was used to create an instructional tool utilizing sign language and allowing for the use of connecting the sign to written language for the development of literacy and language (Aedo, Miranda, Panetsos, Torra, & Martin, 1994).

Technologies Applied to the Field

Technology had provided for the creation of text telephones (TTY) and other telecommunication technologies, which have seen an increase in access as continuing technology has allowed for convenience in size and mobility (Beck, 1995). Over time the TTY has been often exchanged for computers, allowing individuals to communicate "disability free" via e-mail, instant messages, and chat rooms (for example, Beck, 1995; Weiserbs, 2000).

Decoders were built into televisions and films were closed-captioned for educational purposes (Hairston, 1994), which opened educational avenues in school to a large amount of material previously inaccessible to individuals with a hearing loss (Caldwell, 1981). Real-time captioning was initially used to provide a visual process for print to assist with language acquisition (Stuckless, 1981) and has since moved to lectures and live news to provide access to current information.

Assistive listening devices have been created to provide access to auditory components of the educational setting. Audio loop systems provide mobility in the classroom for students with very mild or temporary hearing loss (Beck, 1995; Nelson & Nelson, 1997). FM systems are set up as radio signals to provide clarity of auditory information in one-on-one and group settings (Lewis, 1995). The research has demonstrated how FM systems have impacted (Boothroyd, 1990) and improved the educational setting for all degrees of

hearing loss (Crandell & Smaldino, 1999; Flexer, 1997; Flexer, Wray, Black, & Millin, 1987).

There have been tremendous advancements in technological tools and the infusion of computers for instruction with students who are deaf/hard of hearing. The technology and the professionals in the field are at a critical juncture to move forward with future advancements for instruction and learning for students who are deaf/hard of hearing.

GIFTED AND TALENTED

A review of the extant literature on technology as it relates to the field of gifted education revealed three general categories: historical trends, technology as an agent for change, and distance learning. It should be noted that, generally, the literature follows the trends in innovation found in the general technology literature. That is to say, as technology became available in the market, it was quickly infused into the curriculum and programming for gifted and talented students.

Historical Trends

Preparing students for a technologically demanding society is a common theme throughout much of the literature on gifted programming. In an update on a 1978 article on the needs for preparing gifted students for the future, Torrance, Goff, and Kaufmann (1989) identified technology proficiency as a primary goal. Instruction of technology mirrors many of the goals and objectives of gifted education like critical and creative thinking (Corrigan, 1994; Little, 2001; Mann, 1994; Shaughnessy, Jausovec, & Lehtonnen, 1997; Weaver & Wallace, 1980). The infusion of computers and technology has not only changed what we teach but also how we teach (Olszewski-Kubilius, 2001). As will be seen later in this article, the promise of technology also addresses the needs of providing programming in rural areas (Spicker, Southern, & Davis, 1988).

There is a positive correlation between technological advancement in society and historical trends identified in gifted education (Corn, 1999; Imbeau, 1999; Stewart, 1999). Advances in technology have provided critical impetus for change in the field and will continue to do so both in the implementation and curricular aspects of programming for the gifted.

Agent for Change

There are numerous articles in the literature on gifted education that describe attempts to infuse technology into the classroom. In these cases, technology is seen as a tool that affects various levels within the curriculum. As an

agent for change, technology can be infused to enhance a single lesson or to alter the entire philosophical nature of the curriculum.

Technology can be viewed as either a means to an end or the end itself. The literature is replete with articles that describe technology as a vehicle for conveying content. In these cases, the content or skills are the primary goal of the instruction, and the technology is infused to accentuate or facilitate the instruction. Traditionally, the use of technology was more commonly found in areas like math and science enrichment. Robotics, Logo, and other computer-aided design programs were popular additions to the activities in math classes (Grandgenett, 1991). Early on, Doorly (1980) promoted the use of computers in implementing mathematics instruction. She found developmental gains in the primary grades in basic number operations. Learning to develop computer programs was also a popular use of computers in math programs (Hershberger & Wheatley, 1989). By the nineties, the use of technology began to permeate other areas such as art, language arts, and thinking skills training (Banbury, Walker, & Punzo, 1990; Bowen, Shore, & Cartwright, 1992; Heaney, 1992; Riley & Brown, 1997; Smith, 1994; Troxclair, Stephens, Bennett, & Karnes, 1996).

Similarly, the literature also follows the trends in computer and technology advancement. Early articles discussed the use of computer-assisted technology and software packages like Logo, Hyperstudio, and various word-processing, spreadsheet, and basic drawing programs (Beasley, 1985; Flickinger, 1987; Jensen & Wedman, 1983; Kanevsky, 1985; Sisk, 1978). Later, the interest in more complex tools like interactive video, multimedia, artificial intelligence, virtual reality, and simulation software became more prevalent in the literature (Barr, 1990; Benno, 1998; Boyce, 1992; Bulls & Riley, 1997; Lewis, 1996; Riley & Brown, 1998a, 1998b; Strot, 1997a, 1997b; Wellington, 1993).

Additionally, using computers as tools to enhance the established curriculum was also noted in the literature. Howard (1994) suggested that using computers could enhance the learning opportunities for students who are gifted/learning disabled. Ross and Smyth (1995) described the importance of promoting thinking skills and how computer formats may enhance students' experiences with more difficult skills. Strot (1998) suggested that individualized instruction could be enhanced by the infusion of computers into research design and implementation projects. Simulation programs, database design, and research can all be added to existing research projects to further augment established activities. Similar studies described the infusion of technology into established units of study to improve the learners' experience and interest with the material and skills (Berger, 2001; Christopher, 1999; Duwell & Bennett, 2000; Strot, 1999).

Finally, there were few articles describing empirical studies that employed technology as a variable. Steele, Battista, and Krockover (1982) found in a study of fifth-grade math that infusing technology positively influenced the students' affective and cognitive outcomes. In a study of elementary and mid-

dle school students, Middleton, Littlefield, and Lehrer (1992) found gender and age differences on student attitudes for activities that included computers. Following a review of the literature on mathematics, Sowell (1993) suggested that further research is needed in the area of the effectiveness of computers in math programs. Shermis, Fulkerson, and Banta (1996) studied the use of computerized adaptive math tests and made suggestions for the potential this technology could have on talent identification. Kaniel, Licht, and Peled (2000) found similar positive results in a study using computer software to enhance metacognitive skills.

In addition to following trends in availability, as technology has become more prevalent in schools and society in general, there has been a subsequent increase in the literature on the philosophical nature of infusion. Morgan (1993) discussed infusion in terms of general school reform. Infusion was seen as a vehicle for impacting productivity and enhancing the instructional environment. Most recently, distance learning has become a popular avenue for instruction employing technology, which greatly alters the instructional environment and has had a direct impact on pedagogical change.

Distance Learning

The final category, comprised of various issues related to distance learning, has become a popular topic in the literature on gifted education. Articles in this category describe both the how-to issues and those related to pedagogical change.

Although Spicker, Southern, and Davis (1988) referred to the importance of distance learning for rural programs, there are few references to this important aspect of technology until later in the next decade. Like Spicker et al. (1988), McBride and Lewis (1993) asserted that telecommunication courses provide valuable resources to learners in rural areas because they provide resources to students that would otherwise be unavailable. This philosophy is one that is behind the distance learning opportunities like the Education Program for Gifted Youth (EPGY) at Stanford University that provides computer-based accelerated math and science courses for students across the country. Several authors have reported on the effectiveness of this instructional delivery system for students who require accelerated programs (Gilbert-Macmillan, 2000; Ravaglia, Suppes, Stillinger, & Alper, 1995; Washington, 1997).

Caution should be taken by those who wish to incorporate distance learning into the curriculum for gifted learners, as the very same objectives and standards should be applied to distance education as to other forms of instruction for gifted learners (Adams & Cross, 2000). Distance learning provides many positive outcomes for gifted learners but care must be taken that the technology does not overpower the users. Interaction and rigor can be maintained but must be carefully planned. Berger (2000) discussed how the rapid growth of the Internet could be used to make learning more accessible because of the pleth-

ora of resources now available via the World Wide Web. Teachers, however, need to be well versed in these resources in order to maximize the experience for learners. McKinnon and Nolan (1999) made excellent recommendations for programs using distance learning. Their emphasis was on the interactive nature of the technology, but advise that organization is the real key to success.

Many articles described specific programs, either intra- or extracurricular, that used computers within the expected coursework. These publications described the program specifically, and the technology was mentioned as part of the overall plan of the program. In other words, the technology used was not integral to the overall program but simply a small component of the coursework. It is worth noting that computers and technology are common features to gifted programs, whether within the scope of the curriculum or used as part of an enrichment program.

OVERALL TRENDS

The use of technology as reported in the literature on special education follows the historical timeline of available technology. Computers have been used in the various special and gifted education programs for as long as they have been available. Likewise the complexity of the infusion within programs mirrors the profundity of use by the wider society. As technology becomes more commonplace in schools and the sophistication of student use increases, the issues become more philosophical in nature. Educators need to be aware of their own pedagogical beliefs and beliefs about technology since these beliefs direct the modification and implementation of innovative technologies for the classroom (MacArthur, 2001).

It is evident that the infusion of technology is specifically tied to the mission and goals of the special education program. For example, the literature reveals that technology for students with learning disabilities is characterized by remedial, instructional enhancement, and productivity tools. Technology involving students with mental retardation is slowly shifting from remedial to functional skills acquisition, addressing the demand for lifelong skills and community integration. In the literature regarding individuals who are deaf/hard of hearing, technology is infused for auditory enhancements and overall access to the curriculum. Within the gifted and talented literature, technology is used to enhance or enrich the curriculum.

CONCLUSION

Educators need to provide each student with an appropriate education that meets his/her need for challenge, interest, and learning style. Educators now have to ask themselves whether the use of technology provides support and ac-

cess for the learning activity, enhances the activity, or detracts from the effectiveness of the instruction. Technology is a tool; it is a means to an end, and that end is learning itself. The impact of technology is moving beyond integration at the classroom level to infusion at the curricular level.

While some continue to search for the perfect "teaching machine," many have abandoned this quest in exchange for a different vision. Gradually, a shift has occurred from using technology to provide remediation through drill-and-practice applications to encouraging students to use the computer in more self-directed ways to encourage critical thinking.

Students with exceptionalities generally look forward to using computers in the classroom and teachers capitalize on this desire. Unfortunately, research has indicated that teachers rationalize using computers in classrooms largely on the basis of its potential benefits for motivation and self-esteem and not on academic value or gains to achievement (Woodward & Rieth, 1997). More needs to be done to illustrate the curricular value of technology that reinforces what we value most in education, learning. Providing an appropriately challenging environment does not have to be at the expense of the curriculum. Technology can provide a vehicle for instruction that respects the needs of all learners without compromising the act of learning.

Review of the literature revealed that classroom technologies have the potential to positively impact the academic growth and development of students with exceptionalities. These students have benefited from the purposeful use of technology. However, for technology to truly make an impact in special education, a push toward deeper infusion into the curriculum is needed. Those with exceptionalities must find technology accessible and available, and teachers must be comfortable incorporating it into their daily instructional routines. Technology can and should move to a more "transparent" position, as teachers and students are able to use it more easily and creatively. In this type of classroom, teachers and students "see through" the technology and are able to better focus on more advanced learning goals of the curriculum.

The infusion of technology into the classroom and curricula during the late 20th century was largely reactive in nature. With limited coursework in teacher preparation programs, limited in-service exposure to technology, and the sheer speed of technological advances, educators were limited in their ability to thoroughly understand and fully infuse technologies that were currently available. The good news, however, is that, as technology advances there will be more user-friendly hardware and software from which to choose. In addition, as technology becomes more integrated into daily life, there will be a natural evolution into the classroom.

As we progress into the 21st century, a more proactive approach to the infusion of technology into the classroom and curricula is occurring. No longer are we as educators content with simple activities that allow students to use already-mastered skills. The primary thrust for infusion has infiltrated curriculum planning with an emphasis on scope and sequence. A major emphasis in

teacher preparation programs to address the priority of infusing technology in all education is reflected in federal grant initiatives like Preparing Tomorrow's Teachers to use Technology (PT3). The emphasis for these grants is appropriately on training at all levels, including training the trainers in education programs.

In conclusion, this review has revealed that within the field of special education, there is considerable consensus with regard to the use of technology in the classroom. While there are variations in the specific hardware or software employed, there is much overlap in basic pedagogical issues. Infusion of technology is non-negotiable in all educational settings and for students of all abilities.

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