JSET
JOURNAL OF SPECIAL
EDUCATION TECHNOLOGY

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Journal of Special Education Technology is a refereed professional journal that presents up-to-date information and opinions about issues, research, policy, and practice related to the use of technology in the field of special education. JSET supports the publication of research and development activities, provides technological information and resources, and presents important information and discussion concerning important issues in the field of special education technology to scholars, teacher educators, and practitioners. JSET is a publication of the Technology and Media (TAM) Division of the Council for Exceptional Children.

The goals of TAM include:

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- Encouraging the development of new applications, technologies, and media that can benefit individuals with exceptionalities.
- Disseminating relevant and timely information through professional meetings, training programs, and publications.
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Call For Applications
EDITOR
Journal of Special Education Technology

The Executive Committee of the Technology and
Media Division (TAM) of the Council for Exceptional Children
announces a search for Editor of the ***Journal of Special Education Technology (JSET).***
An individual or team is sought to take over management and production
responsibilities of the journal beginning January 1, 2006.
The position requires previous publishing and editing experience
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The editor of the *Journal of Special Education Technology*
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Introduction to the Special Issue on Technology Use by Students with Intellectual Disabilities

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The articles and some of the columns in this special issue focus on technology use by students with intellectual disabilities. In the *Findings and Purposes* section of the 1988 Tech Act (PL 100-407) Congress stated that the provision of AT devices and services to individuals with disabilities enables "individuals to: (a) have greater control over their own lives, (b) participate in and contribute more fully to activities in their home, school and work environments, and in their communities, (c) interact to a greater extent with non-disabled individuals, and (d) otherwise benefit from opportunities that are taken for granted by individuals who do not have disabilities" (p. 1044). These are outcomes valued by most citizens. However, as discussed in the first article in this special issue, it appears that the promise of AT has been, largely, unfulfilled for people with intellectual disabilities.

A focus on technology use by people with mental retardation is a fairly recent phenomenon. In 1982, the national headquarters of the Association for Retarded Citizens (now The Arc of the United States) launched a programmatic initiative called the Bioengineering Program, intended to address the lack of focus in technology development for people with mental retardation. For more than a decade, this program developed technology for and advocated on behalf of people with mental retardation (Brown & Cavalier, 1992; Cavalier & Brown, 1998; Mineo, 1985; Mineo & Cavalier, 1985). By the late 1990s, educators, family members, and the general public's awareness of the potential of technology had grown, including as it pertained to the education of students with disabilities. For example, the Reauthorization of the Individuals with Disabilities in Education Act in 1997 mandated that the IEP of every child with a disability consider AT as an option as part of the student's program. The establishment of the Coleman Institute on Cognitive Disabilities at the University of Colorado in 2001, further raised the visibility of issues pertaining to cognitive access.

We believe that this issue is timely for a number of reasons. First, there is the aforementioned increased visibility of issues pertaining to ensuring cognitive access. Second, it is increasingly evident that technology will play a major role to ensure universal access to learning for all students, including students with intellectual disabilities, and thus it is important to consider what works and what is needed with regard to this population.

Third, we are in the midst of a reconceptualization of what it means to have an intellectual disability in which technology can play an ever broader role. The 9th Edition of AAMR handbook on definition and classification of mental retardation (Luckasson, et al., 1992) introduced a functional definition and classification system intended to link the classification of mental retardation to a system of supports. In this edition of the AAMR classification manual, *mental retardation* is defined not as something that a person *has* or something that is a *characteristic of the person*, but instead as a *state of functioning* in which limitations in functional capacity and adaptive skills must be considered *within the context* of environments and supports. Luckasson, et al. (1992) noted "mental retardation is a disability *only* as a result of this interaction" (p. 10); that is, *only* as a result of the interaction between the functional limitation and the social context, in this case the environments and communities in which people with mental retardation live, learn, work and play.

The functional definition of mental retardation by the AAMR emphasizes the interaction between the person with the disability and the context in which he or she lives, learns, works, or plays. By defining *disability* as a function of the interaction between the environment and a person's functional limitations, the focus of the problem shifts from being a deficit within a person to the identification and design of *supports* to address that person's functioning within that context, with an enhanced focus on accommodations and modifications to the context. Technology, thus, becomes a critical support to enhance performance across multiple environments, including school.

In the first article in this special issue, Wehmeyer, Smith,Palmer, and Davies overview the literature pertaining to technology use by individuals with intellectual disabilities, and examine barriers to that use. The second article, Parette and Wojcik, examines the idea of creating a technology toolkit that would be useful with students with intellectual disabilities. In the next manuscript, Hutcherson, Langone, Ayres, and Clees report on a study of computer assisted instruction to teach a functional skill important for many students with intellectual disabilities, grocery shopping. Fourth, Stock, Davies, and Wehmeyer present a pilot study of the use of a multi-media tool to enable persons with intellectual disabilities to indicate preferences in vocational and employment options. Finally, Braddock, Rizzolo, Thompson, and Bell provide a look at emerging technologies that may benefit individuals with cognitive and intellectual disabilities.

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Technology Use by Students with Intellectual Disabilities: An Overview

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Technology is a prevalent feature of educational environments today. Unfortunately, in too many cases students with intellectual disabilities do not have access to or are not able to use such technologies. This article overviews the literature pertaining to the use of technology by students with intellectual disabilities, examines characteristics of this population that impact technology use, and provides a review of the literature pertaining to technology use by students with intellectual disabilities across several functional domain areas.

The U.S. Department of Education report *"Computer and Internet Use by Children and Adolescents"* (National Center on Educational Statistics, 2001) illustrated the degree to which technology use, particularly electronic and information technologies like computers and the Internet, has become a pervasive part of the educational process. This study found:

1. About 90% of children and adolescents ages 5–17 (47 million) use computers and about 59% (31 million) use the Internet.
2. About three-quarters of 5-year-olds use computers, and over 90% of teens (ages 13–17) do so. About 25% of 5-year-olds use the Internet, and this number rises to over 50% by age 9 and to at least 75% by ages 15–17.
3. More children and adolescents use computers at school (81%) than at home (65%). (NCES, 2001, p. iv).

Unfortunately, the National Center on Educational Statistics (NCES) also found that 5 to 17-year-olds without a disability were significantly more likely to use computers and the Internet than their peers with disabilities. Furthermore, even among students with disabilities it is likely that students with intellectual disabilities are less likely to have access to and benefit from technology. The reasons for this are varied, certainly, but essentially there have been few efforts to ensure that computers and other technology devices are cognitively accessible. The National Council on Disability (1996) noted:

> "…other than trying to make computers generally easier to use, no specific features targeted at users with cognitive / language impairments are known to be part of current computer design, nor have any been included in any of the design guidelines that would not have been included in the set of guidelines for making products easier to use by this population."

This article overviews technology use by students with intellectual disabilities, with a particular focus on electronic and information technologies, such as computers, that are widely used in education. Issues pertaining to barriers to such use for this population are also examined.

Technology Use by Students with Intellectual Disabilities

There are only a few studies examining the degree to which students with intellectual disabilities use technology. Derer, Polsgrove, and Rieth (1996) investigated assistive technology (AT) use in classrooms by surveying teachers who worked with students with disabilities. These researchers found that students with intellectual disabilities constituted between 10% and 23% of students with disabilities using AT, and that 34% of students with intellectual disabilities were using some form of AT. Derer and colleagues identified six barriers to technology use for students with disabilities, including locating and procuring equipment, lack of time for training students and teachers to use the equipment as well as time to obtain and prepare equipment for use, high cost of devices and the lack of funds to access devices or services, and teacher knowledge about and training in the area of assistive technology.

The Arc, a national association on intellectual disabilities, conducted a national survey of parents regarding the use of technology by their school-age son or daughter with an intellectual disability (Wehmeyer, 1999). The survey consisted of five areas of questions focusing on the use of technology for a specific purpose: (a) mobility technology devices, (b) hearing and vision technology devices, (c) communication technology devices, (d) home adaptations, and (e) environmental control and independent living devices. An additional set of questions tapped into the student's use of personal computers. Specifically, the survey solicited information about technology use in each functional area and computer use and availability, unmet needs with regard to each of the functional areas and computer use, barriers to technology use, training to use the technology, and satisfaction with technology use.

Although a wide array of devices were used by students with intellectual disabilities, the most striking finding was that in four of the five use-specific areas, the percentage of students who could potentially benefit from assistive devices but did not currently have access to such devices was greater than the percentage of students who currently used such devices. Cost was the greatest barrier identified, followed by information about devices and device complexity.

With regard to computer use, 68% of respondents indicated there was a computer in their home, and an additional 15% indicated that their son or daughter had access to a computer in another environment, mostly in school programs. When asked to identify what the student with an intellectual disability did with the computer, most noted educational activities. For respondents whose family member did not use computers either at home or elsewhere, 78% indicated they believed that their family member could benefit from a computer. The most frequently cited barrier to computer use was the cost or lack of funds, followed by the lack of training available, lack of information about what the computer could do to benefit the family member, the complexity of the device, and the lack of assessment.

In summary, The Arc's survey found that students with intellectual disabilities generally underutilized technology. In most functional-use areas, more students who might benefit from assistive technology devices did not have them than students who did. Device cost, training, assessment, and complexity were identified as primary barriers. Encouragingly, however, 83% of students had access to a computer somewhere, although the range of activities for which these computers were used was limited. The survey did not determine Internet use, but as explored subsequently, there is reason to believe that many people with cognitive disabilities have only limited access to the Internet.

Barriers to Technology Use by Students with Intellectual Disabilities

There are several reasons students with intellectual disabilities do not use technology, but two seem particularly important; the characteristics of students with intellectual disabilities that limit their technology use and the lack of universal design features that take into account issues of cognitive accessibility.

Characteristics of Learners with Intellectual Disability That Impact Technology Use

The Arc's study focused mainly on barriers external to the learner, like funding, training, or maintenance. However, one of these external barriers, device complexity, is in essence a function of learner characteristics and the abilities students bring to bear in using technology. Characteristics of learners with intellectual disabilities typically involve impairments in the following cognitive ability domains: (a) language, communication, and auditory reception, (b) reasoning, idea production, and cognitive speed, (c) memory and learning, (d) visual perception, and, (e) knowledge and achievement (Carroll, 1993).

In general, to promote technology use by students in this population, educators need to consider issues pertaining to these areas of limitation in cognitive abilities and ensure that technology adequately addresses them. We have recently conducted comprehensive examinations of the impact of these limitations on technology use by students and adults with intellectual disabilities (Wehmeyer, Smith, and Davies, in press; Wehmeyer, Smith, Palmer, Davies, & Stock, 2004) and briefly summarize the findings from these examinations in this section.

Language and Communication Ability and Auditory Reception

Impairments in language and communication ability impact technology use in several ways. Impairments in receptive and expressive communication skills limit the degree to which some students with intellectual disabilities will be able to utilize technology, particularly the expanding class of telecommunication technologies. Additionally, a growing means of inputting information used by technology (e.g., computer programs) involves speech input devices. Problems of speech articulation pose barriers in both cases, but other factors pose problems with these and other technologies. Similarly, more complex verbal instructions, such as those often found in voice mail systems, may limit use for people with cognitive impairments.

Impairments in reading and writing abilities also introduce barriers to effective technology use. The most obvious is often that the primary input mode to access a wide array of computer technology involves typing or, with newer handwriting transcription technologies, writing abilities. Even when input is not required, most software programs require rather high levels of reading ability to navigate. Many instructions to technology use and maintenance are written, often in overly complex formats that people with intellectual disabilities cannot read or understand. Although the technology field is increasingly embracing the use of more universally accepted graphics to communicate information, most technology continues to rely primarily on text to present program options and provide instructions to users.

Technology devices often emit tones and other sounds intended to convey meaning. Often, however, it is difficult to discern their meaning even for experienced technology users. With computers, the audio signal is many times accompanied by a text message in a message box or somewhere else on the computer screen. Technology developers generally assume the ability for users to read the accompanying text message. The need to read to understand the meaning of the audio signal thus limits the number of users with intellectual disabilities who can understand the computer-generated message.

The language involved in technology use is often not consistent with that of everyday communication. Terminology used in some technology systems is often complex and may introduce new definitions of common terms. For example, a menu in a computer program, while conceptually similar (i.e., an array of choices) to the common use of menu at a restaurant, may confuse a student with an intellectual disability. Many examples of these language-related barriers can be identified by considering the terms used in common software applications (e.g., file, tools, window, drive). Use of terms with multiple meanings and abstract metaphors (e.g., files, folders) can pose barriers to people with intellectual disabilities, who respond to language based on a more literal, concrete representation of the world.

Reasoning, Idea Production, and Cognitive Speed

Reasoning abilities involve capacities in areas such as sequential reasoning (i.e., deductive, logical, and verbal reasoning, symbol manipulation, match problems), inductive ability (i.e., requiring a person to inspect a class of stimulus materials to infer a common characteristic), and quantitative reasoning (e.g., those requiring reasoning based on mathematical properties and relations, including critical evaluation, arithmetic reasoning and problem solving, math aptitude, and number series, classification and operations). Idea Production refers to abilities required for individuals to produce ideas and communicate them, including ideational fluency, naming facility (i.e., naming common concepts), associational fluency (i.e., producing words/concept that are associated), expressional fluency, word fluency, sensitivity to problems, originality/creativity, figural fluency (i.e., producing original drawings or sketches), and figural flexibility (i.e., solving figurative problems).

In that these domains encompass abilities that are considered to be at or near the core of what is ordinarily meant by intelligence, it follows that they significantly impact the ability of students with intellectual disabilities to use technology. For example, virtually all appliances, devices, and software systems require some level of sequential reasoning, even if it is as simple as having the ability to assess whether the system is turned on or not. This may be true for a wide range of simple to complex technologies, from knowing whether the iron is on, to activating an augmentative communication system. To the more complex side of things, most computer programs are complex and interactive, requiring the user to constantly take actions and draw conclusions from the system's reaction as to what is the most likely next move.

The impact of limitations in numeracy on technology use can also be seen in the many systems that involve numerical comprehension and manipulation. From setting a stove temperature and dialing a telephone to using calculators and entering data, situations abound where limitations in numeracy skills impact technology use. Limitations in this area can be compensated for by providing non-numerical interventions to improve access, such as in picture-based speed dial telephones or special markings on dials or switches to cue the user to a specific setting or switch when many choices are available.

Mainstream computer programs invariably offer a myriad of interface choices at any given time, many of them providing multiple input options for the same output (e.g., text menu, key board shortcuts, button toolbars). Specialized computer programs can be created that utilize a limited number of repetitive processes that are largely linear in nature. This means that at any given time while interacting with the software either a single choice is available for the next step, or system-generated cues such as audio prompts guide the user to the next-most-likely action. Other examples of limiting choice options to make technologies more accessible include desktop software that provides access to a limited set of computer features or augmentative communication device and keyboard overlays that reduce or reprogram available keys.

Other technologies present their own challenges to the capacity of students with cognitive impairments to reason abstractly. Communication devices often include customizable pictures or text buttons that, when pressed, speak the indicated word or phrase. To provide added functionality, most of these devices include a feature that allows the user to create different overlays, or layers, so that more words or phrases can be accessed. For example, a typical device may have 16 buttons that can be programmed to speak a designated phrase. But an additional switch allows the user to activate another layer of programming so that the same 16 buttons can speak entirely different phrases. However, many of these devices are not usable by students with mental retardation, due in part to the inability to conceive of these different layers.

Other examples may be as simple as failure to recognize or understand the meaning of when the computer cursor arrow turns into a hand icon when it is placed over a clickable element of a Web site, or in understanding the difference between a single click, a double click or a right-click. Even the most basic of software features—such as in the practice of disabling or graying-out buttons when they have no practical use—often are too subtle to be recognized by users with cognitive disabilities.

Using technology on a regular basis often entails problem identification and problem solving by the technology user that may serve as a barrier to people with intellectual disabilities. Many technology users rely on their ability to generalize previous learning to problem solve unexpected occurrences. However, many individuals with intellectual disabilities have limited ability to generalize learning from one situation to another and therefore do not develop the workaround strategies that users of technology develop to overcome problems. This may be due to the learning demands related to the acquisition of knowledge and skills to use a program or device, lack of experience with the technology, excessive complexity, poor interface design, program or system bugs and failures, or conflicts with other technologies.

Cognitive Speed abilities include skills in areas such as rate-of-test-taking and reaction time. Limitations in these abilities may impact technology use. Current technology devices generally have ample processing power, and do not require users to wait for very long for actions to be accomplished. One exception, however, is the area of utilizing dynamic content and applications delivered over the Internet. While access speeds are increasing rapidly, there still can be delays when using Web applications due to the type of connection as well as the type of media being delivered (e.g., streaming audio and video). The inability to detect when to wait for a program or Web page to catch up after making user inputs can lead to errors as users may click buttons multiple times waiting for the program to do what it is supposed to do, without realizing that the first button press was sufficient.

The ability to respond quickly to operate technology devices can also be an important factor in technology operations for students with intellectual disabilities. For example, some ATMs require users to make inputs within very short time spans. If a person is slow at making an input, the ATM will either display a text message such as "Do you want to continue?" — which many people with intellectual disabilities would not be able to read — or may simply end the activity. Some ATMs, when expelling the ATM card for the user to take, sound an audio tone for a short time and, if the card is not taken quickly, the card may be taken back into the machine and kept. Cognitive speed limitations that impair a student's ability to use technology fast enough can introduce barriers to technology use.

Memory and Learning Skills

Mainstream technology interfaces are often complex as developers seek to provide users with a wide array of program features that, in the end, require the student to learn and remember multiple steps to complete a process. Too often this occurs at the expense of simplicity of use. Thus, while many students without cognitive disabilities may find these interfaces challenging, their complexity often renders the technology system unusable by students with intellectual disabilities. For example, many students with intellectual disabilities have difficulty performing personal budgeting activities independently. There are now several commercially available software programs that automate the functions associated with balancing a checkbook, paying bills online, and maintaining a budget. With such supports, students with intellectual disabilities may only need to be taught how to input data, as opposed to the skills related to math, which are less attainable for many students. However, almost without exception, the interfaces for these software programs are too complex and confusing for use by people with cognitive impairments and, in the end, they are unable to use them to perform the function for which they are intended.

When considering technology supports for students with memory and learning limitations, technology designers must provide intuitive interfaces without overwhelming students with too many options. Often it is better to provide a single, consistent approach to performing a program function than providing multiple methods for accomplishing the same task. For example, in most Windows-based word processing systems, computer users can copy and paste text in a variety of ways: (a) highlighting the text and making appropriate selections [edit – copy – edit – paste] from the text toolbar and dropdown menu, (b) highlighting the text and clicking on the copy icon on the toolbar, followed by the paste icon, or (c) highlighting text and right-clicking on the highlighted text, then selecting copy and paste from that menu. Such a range of options may be too complex for some students with intellectual disability for whom it may be simpler to stick to one modality (e.g., using the icons on the toolbar) across multiple task activities. In general, devices that require users to memorize and learn long sequences of commands to succeed present barriers for students with intellectual disabilities.

Visual Perception Abilities

Visual Perception Abilities refer to the cognitive component of vision (i.e., as opposed to impairments to sensation, such as blindness), including impairments in visualization, spatial relations, closure speed (i.e., the ability to combine disparate visual stimuli into a meaningful whole), closure flexibility (i.e., ability to manipulate, visually, multiple objects or configurations, such as hidden figure tasks), serial perceptual integration (i.e., integrating sequential images), spatial scanning (i.e., speed in exploring a visual field), perceptual speed (i.e., speed of finding desired images or stimuli), imagery (i.e., ability to image or visualize performance or action sequence), length estimation, perception of illusion, and perceptual alternations. These factors relate to the abilities in "searching the visual field, apprehending the forms, shapes, and positions of objects as visually perceived, [and] forming mental representations" (Carroll, p. 304).

Limitations in visual perceptual ability can have a significant impact on one's capacity to operate software programs and in particular, software operating systems. As graphical user interfaces using pointing devices such as a mouse or touchpad have evolved and become the dominant mode of interacting with computers, the ability to scan, locate and act upon key information on the display screen has become of paramount importance. Attending to relevant environmental cues can often be difficult for students with intellectual disabilities, and this difficulty also exists when viewing complex displays, with potentially many windows, buttons, and other screen elements. Larger computer monitors combined with increasing display resolutions provide the capability to populate the computer display with many windows and graphical elements including icons, menus, and other images. Without careful attention, screen clutter can be very distracting and can make managing a computer session very difficult or impossible for users with visual spatial limitations

Another significant limitation can result from difficulty mastering the skill of moving the mouse or other pointing devices and associating that with moving the arrow or pointer on screen. With most computers, the predominant input control device is a mouse, trackball, or touchpad. The ability to successfully correlate hand movements with the movement of the arrow on screen is necessary to use these standard input devices. Touch screens are often a good alternative given their direct cause effect function, but they are still more expensive and are not standard equipment with off-the-shelf commercial systems. In addition, touch screens are only useful if the software applications that will be used have a user interface designed with larger buttons and controls to allow them to be selected with a finger on the display.

Additionally, visual perceptual impairments can impact a student's interactions with virtually any type of technology device, including difficulty in following instructions for the device use, difficulty with operating device controls, and so forth.

Knowledge and Achievement Abilities

Knowledge and achievement abilities involve general school achievement, verbal information and knowledge, information and knowledge in mathematics and science, technical and mechanical knowledge, and knowledge of behavioral content (personal-social interaction knowledge). Computers are common tools for acquiring new knowledge and generating new works of achievement and are used to learn about nearly any topic as well as to produce, such as in writing, composing music, or generating artistic works. The majority of software applications that have been used for students with intellectual disabilities to acquire new knowledge or abilities have been developed for other groups, primarily for children. Thus, age-appropriateness has often been absent when it comes to learning software for students with intellectual disabilities, as few applications have been designed with the appropriate user interfaces and with ranges of appropriate content. Early reading or basic math programs may be beneficial for some students, but generally the programs that are available are not age-appropriate for older students and adults with intellectual disabilities.

Programs for writing, such as word processors, may be useful for a minority of users with intellectual disabilities who have attained some level of literacy skills. Better success may be achieved in using painting and graphics programs, although these vary greatly in complexity of operation. Simpler-to-use drawing programs allow users with intellectual disabilities a vehicle for artistic expression, but there are also barriers to independent use. Mouse skills are usually required, which often presents a barrier. Alternative input devices can be used effectively, however, including graphics tablets or touch screens. Saving files and printing the finished product may also be difficult as menus and print options may be difficult to navigate. There appears to be a great opportunity for innovation in the area of creating software applications that can be used independently by individuals with various levels of cognitive ability to generate creative content.

Features of Technology that Address User Characteristics

Universal Design

Journal of Special Education Technology (JSET) readers will be familiar with the principles of universal design as applied to technology design, including equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and appropriate use (The Center for Universal Design, 1997). If all technology devices took into account all of these principles, it is quite likely that many more devices would be useable by students with intellectual disabilities.

However, several might be particularly important in light of the previous discussion on cognitive abilities and the impact of limitations in these areas on technology use. First, devices that abide by the *flexibility in use* principle inherently accommodate for use by a wider range of individual preferences and abilities. This includes providing options that accommodate for users' accuracy and precision, and adapt to a user's pace. For example, computer programs providing multiple input and output options (e.g., auditory, visual, icon) fit this category, as do telephones that have larger buttons with more space between numbers (The Center for Universal Design, 1997). Issues of *simplicity and intuitiveness of use* are obviously important for students with intellectual disabilities. As noted previously, many devices are overly complex and operate counter to users' expectations, including common appliances such as VCRs and alarm clocks. Universally-designed devices also typically provide some supports (prompting, graphic, visual, or audio directions) for use. The principle of *perceptible information* requires not only that information needed to operate the device be easily seen, but also that such information be provided in multiple modes, with redundant presentation of information.

Finally, an important and often overlooked feature for students with intellectual disabilities is the principle of *tolerance for error*. As noted previously, students with intellectual disabilities frequently make mistakes in using technology and if that error results in a failed use, the device becomes essentially impossible for students to use. Developing technology that never encounters unexpected errors is virtually impossible. However, given the difficulty many students with intellectual disabilities have responding to unexpected errors, it is imperative that priority be placed on identifying highly reliable technology supports for these students. Device failure is often a function of device complexity. The more complex a device is and the more features it has, the more likely it is to have unexpected errors. At times it may be more important to identify less complex devices with fewer features if they provide the benefit of greater reliability. Moreover, many devices have, in essence, a one-strike-and-you're-out policy where one error (e.g., wrong key stroke, wrong button) results in the failure of the user's session. For example, the value of a dialogue box that prompts you to confirm a selection (e.g., deletion, exit) becomes evident when you inadvertently hit the exit icon without having saved work on an ongoing activity. The dialogue box allows you to select Cancel and does not immediately delete unsaved work. Students with intellectual disabilities need devices that minimize the potential for error, but also which allow errors to occur without dire consequences.

Another example of how features of technology address the characteristics of users with intellectual disabilities involves recommendations from the Telecommunications Access Committee (1999), which was commissioned to look at engineering and design features that would ensure access to telecommunications technology for people with cognitive disabilities. This committee identified four classes of strategies that achieve this: (a) redundant, user-controlled modality of information, (b) streamlined, user-controlled amount and rate of information, (c) procedural support, and (c) content organization.

Strategies to ensure that the device design contains redundant, user-controlled information include the use of visual examples (e.g., diagrams, graphic icons, line drawings), in addition to or instead of text, providing information both in visual and auditory formats, providing descriptions of pictures, captions, and so forth, and allowing multiple methods that allow users to locate and use controls (e.g., shape, size, texture, color, labels, voice output) (TAC, 1999). Allowing users to control the amount and rate of information and streamlining information provided is the second strategy identified. Such strategies support students with attention and memory limitations by allowing a user to control aspects (i.e., size, placement, appearance) of display elements, by providing simple, standardized layouts for devices and controls, presenting information in a step-by-step fashion, keeping needed information available until the user dismisses it instead of timing display changes such as information on the screen of a digital phone, eliminating functions that require simultaneous action, providing mechanisms to speed up, slow down, or repeat information, and using select-and-confirm strategies that involve users confirming they have completed a step in the process (TAC, 1999). Procedural support strategies address executive function, planning, and sequencing issues, reducing memory load and limiting distraction. Such strategies include providing step-by-step instructions, cue sequences and feedback cues in multiple formats, the use of wizards to offer help and support operation, and automating more complex aspects of the technology use (e.g., storing phone numbers in memory). Finally, content strategies include keeping language simple, highlighting key information or providing summaries of information, and so forth.

Technology Use by Students with Intellectual Disabilities: Literature Review

Technology use relevant to students with intellectual disabilities will, necessarily, go beyond how technology is used in the classroom, primarily because the educational programs of students with intellectual disabilities involve content in both core academic content areas and in functional, life skills areas offered in school and in the community. So, in addition to the use of technology for traditional instructional purposes, such as computer assisted instruction, to promote academic progress and achievement, students with disabilities can benefit from technology to support learning in a wide array of life skills areas. In this section we examine the literature pertaining to the use of technology by students with intellectual disabilities within seven functional use areas: (a) communication, (b) mobility, (c) environmental control, (d) activities of daily living and community inclusion, (e) education, (f) employment, and (g) recreation and leisure.

Communication

Being able to communicate is, of course, a critical skill that facilitates student interactions with others, including peers and adults, and enables students to meet their basic needs. Romski and Sevick (1988) noted that the field has adopted a broad definition of communication, including vocalizations, gestures, and other modes of expression, from among which technology plays a central role. A number of research studies have identified the importance of using technology to provide alternative means of communication for persons with multiple and cognitive impairments (Blischak, 1999; Meyers, 1994; Schepis, Reid, Behrmann & Sutton, 1998).

Augmentative and alternative communication (AAC) involves the use of technology in the form of voice output communication aids (VOCA) and synthesized speech, but may also include a wide array of options for communication from low-tech message boards, signing, symbols, pictures and visual prompts to very complex technology (Blamires, 1999; Blischak & Lloyd, 1996; Hooper & Hasselbring, 1985).

Sigafoos and Ianoco (1993) suggested that, in selecting such a device, a student and his or her family, in conjunction with a wider team of related services personnel, should look at such factors as symbol options (e.g., real objects, photographs or line drawings); the representation of the message and how that message is accessed (e.g., direct selection, eye gaze, scanning); the options for output such as visual or speech output; and the expandability/ portability of the device, related to storage capacity for communication units and the size/weight of the device.

Research concerning AAC and individuals with intellectual disabilities has focused on diverse, but related aspects of the communication process, including communicative intent (Dicarlo & Banajee, 2000), social interaction (Abrahamson, Romski & Sevcik, 1989), functional communication (Dyches, 1998), symbol recognition (Abrahamson, et al., 1989), and communication to encourage positive behavior support (Danquah, Mate-Kole & Zehr, 1996). Dicarlo and Banajee (2000) evaluated the effects of VOCA devices for young children with significant developmental delays who were not verbal. The *Alpha Talker* (Prentke-Romich) and a *Dual Rocking Lever Switch* (Enabling Devices) using *Picture Communication Symbols* (Mayer-Johnson) were used with two children who were two-years-old. Increased communication initiations were found for these children following baseline observation and training on the use of one of these devices for each child. At any age, VOCA devices: (a) lessen the burden on the listener, (b) serve as a means of getting attention, rather than having to gain attention first before communication starts, and (c) facilitate typical communication by storing messages in advance (Dicarlo & Banajee, 2000; Mustonen, Locke, Reichle, Solbrack & Londgren, 1991). Use of AAC technology has also been shown to improve speech comprehension, speech production, improved attention span, visual attention in a visual-motor task, and improved social interaction in a study conducted with children with intellectual disabilities (Abrahamson, et al., 1989).

Studies have shown the benefit of people with intellectual disabilities using a simple switch to produce functional communication using a tape-recorded message (Dyches, 1998) or to signal the need to continue an activity (Gee, Graham, Goetz, Oshima & Yoshioka, 1991). They have also been shown as effective to support a person to demonstrate a preference or make requests for activities (Wacker, Wiggins, Fowler & Berg, 1988).

Computers can be useful as AAC devices for individuals with intellectual disabilities. Hetzroni, Rubin and Konkol (2002) showed that a classroom PC was used effectively as AAC incorporating eye gaze technology for young girls with Rett Syndrome. Similarly, the System for Augmenting Language (SAL); (Romski & Sevcik, 1996) instructional approach uses computer-based speech output devices to pair symbols with English words. Partners in communicative interactions learn to use the device to augment their speech input to the participant's symbol input, and ongoing resources and feedback to support both communication partners are put in place.

Mobility

Limitations in mobility have implications for most functional life areas, such as employment, recreation, and community inclusion. Despite the pervasiveness of limitations related to mobility among people with intellectual disabilities, there is little research evaluating the use of technology applications to the problem and, in most cases, this literature base has focused only on adult populations, typically adults with cognitive disabilities who are aging and losing ambulation. Nevertheless, some of this research has potential implications for students.

For example, Lancioni, Olivia, and Gnocchini (1996) taught two adults with intellectual disabilities and visual impairments to use a radio/light system to assist in indoor travel in familiar and unfamiliar environments. The device was capable of turning the lights on as the user approached, and subsequently turning them off as the user passed a light source. Researchers programmed both the device and light sources for the appropriate route during test sessions. Results demonstrated that not only were the two subjects able to use the system to orient and move independently in the familiar environment, they were also able to successfully generalize use of the light guiding system to an unfamiliar environment.

Other studies have dealt with more common mobility technologies or addressed gross motor movement for people with intellectual disabilities, as opposed to destination-based movement issues. May (1983) demonstrated that a wheelchair user with severe cognitive and physical disabilities could benefit from a switch-activated system that played music when she lifted her head into a desired position. Similarly, Horn and Warren (1987) used a computer system that activated toy reinforcers to substantially increase motor skills (e.g., pulling, kneeling, sitting up) in two young children with severe, multiple disabilities.

Activities of Daily Living, Environmental Control, and Community Integration

Technology use can support greater independence in activities of daily living, control over one's environment, and enhanced community integration (Anderson, Sherman, Sheldon & McAdam, 1997; Felce & Emerson, 2001; Lancioni, 1994; Johnson & Miltenberger, 1996). In general, the impact of technology use on community inclusion has not been examined directly and is inferred from the capacity of technology to support greater independence in daily living activities and in environmental control, as well as the potential for technology to support greater mobility around the community.

A case study by Lancioni, O'Reilly & Campodonico (2002) supported the efficacy of audio prompts delivered via a portable tape player in reducing the time needed for a young adult with multiple disabilities to complete dressing and washing activities. Similarly, Browning and White (1986) demonstrated the efficacy of interactive video-based instructional materials to promote greater community participation and functional life skills for students with intellectual disabilities, and Langone and colleagues have shown the efficacy of video-based instructional materials to promote community integration skills like grocery shopping (Langone, Shade, Clees, & Day, 1999; Mechling, Gast, & Langone, 2002).

Riley, Bodine, Hills, Gane, Sanstrum, and Hagerman (2001) showed that use of *The Tickle Box* (Adaptive Learning Company), a reminder system that includes a modified pager to help people manage their own activities, by a young woman with fragile X syndrome enabled her to independently complete more daily living tasks than when she was not using the device.

Control over one's environment is also an important component of increased independence to which technology can contribute (Hammel, 2000), though there are few studies that have examined this with regard to individuals with intellectual disability. Lancioni, O'Reilly, Oliva, and Coppa (2001a, 2001b) showed that two boys with multiple disabilities could use microswitches to control aspects of their environment, providing a greater range of response options and opportunities for environmental input than without such switches. Hammel, Lai, and Heller (2002) conducted a longitudinal study of people with developmental disabilities who were aging, and found that a majority of persons had better function with regard to community living outcomes with the use of AT.

Education

The use of computer assisted instruction (CAI) has become more prevalent in schools, though the majority of studies examining CAI focused on commercial math and spelling programs with students with learning disabilities (Hofmeister, 1984; Higgins & Boone, 1990; Horton et al., 1988). For students with intellectual disabilities, studies of the impact of CAI have focused on basic skills and the practice and automation of these skills. Because CAI can be individualized, repetitive, and systematic in its presentation of material, it has been found to be particularly promising for providing extended practice needed to promote the automaticity of basic skills (e.g., mathematics, word recognition) (Kinney, Stevens, & Schuster, 1988).

Lin, Podell and Rein's (1991) study of word recognition improvement typifies a series of comparisons between CAI and traditional instruction. In this study, 45 students with mild intellectual disabilities used a word attack program to strengthen word recognition skills. On the computer screen, the word was first introduced, followed by a phrase, and then a series of complete sentences. The outcome of the drill and practice CAI was an increase in the response rate for students, but no significant change in the number of correct words identified. The increased response rate was attributed to improvement in students' ability to monitor their performance as well as the immediacy of the feedback and reinforcement in the CAI condition. Similarly, Podell, Tournaki-Rein, and Lin (1992) found a decrease on average from 22 seconds to 7 seconds for 71 individuals with a mild intellectual disabilities practicing addition. This exemplifies findings from a series of CAI studies (e.g., Margalit & Roth, 1989; Podell, Tournaki-Rein, & Lin, 1992) that found an increase in response rate but not a significant improvement in correct responses. Results are consistent across an array of academic content areas, including, addition and subtraction, word recognition, and spelling (Farmer, Klein, & Bryson, 1992).

Lin, Podell and Tournaki-Rein (1994) examined CAI and mathematic skills in students with and without intellectual disabilities. In the addition portion of their study they found minimal difference, but in the subtraction portion differences between the CAI and pencil-and-paper conditions was found.

Faster response time was reported and attributed to the inherent features of the computer-based program. Similarly, Leung (1994) found that teaching simple addition to children with intellectual disabilities using a computer could improve sustainable performance and generalize to paper-and-pencil applications and related tests.

The application of CAI to students with intellectual disabilities has also been shown to benefit skill generalization. For instance, Stevens, Blackhurst, and Slaton (1991) delivered instruction on word recognition and spelling via CAI. Student spelling and word recognition performance improved significantly and outcomes indicated that immediate generalization from computer training to teacher-directed handwritten format can occur without the need of continuous computer-assisted feedback. Likewise, Jaspers and Van Lieshout (1994) showed that students who received technology-based external modeling instruction outperformed other children.

Distinct from CAI but equally important in education is research conducted to examine the use of computers or related technologies to assist in the continued engagement of students in the learning experience or a functional task (LeGrice & Blampied, 1994). Lancioni and his colleagues conducted a series of studies to explore the effectiveness of technology and the role it can play in promoting task performance (Lancioni et al., 1999; Lancioni et al., 2000; Lancioni, O'Reilly, Campdonico, & Mantini, 2001). In these studies, an electronic device, similar to a PDA, emitted auditory and tactile prompts (i.e., vibrations) and offered step-by-step instructions in the task to be completed. Lancioni and his colleagues found that the computer-based strategy improved performance across tasks for individuals with moderate to severe intellectual disabilities.

Briggs et al., (1990) examined prompt systems for adolescents with moderate to severe intellectual disabilities focusing on a self-operated auditory prompting system. Like Lancioni and colleagues, Briggs et al. observed generalization of the use of the self-prompting device across settings as well as maintenance of the skill and the problem-solving behavior. LeGrice and Blampied (1994) integrated video prompts to support successful completion of a task. Unlike Lancioni and his colleagues, the video prompting involved preparing the individual to correctly perform the steps. The focus here was to transfer the video prompts to the personal operation of a computer.

Studies of the use of video prompting that emerged in special education technology literature during the late 1980s have examined the impact of this technology across disability categories, including students with intellectual disabilities (Woodward & Rieth, 1997). Both Cuvo and Klatt (1992) and Wissick, Lloyd, and Kinzie (1992) used multimedia technologies to assist learners with intellectual disabilities to learn to tell time, with the latter also focusing on teaching students to understand directions, discriminate the worth of coins, and develop appropriate social skills.

From early examinations, researchers have expanded multimedia applications reflecting a constructivist approach to learning. Rather than teacher-directed instruction, multimedia-based efforts have fostered learning through media tools. According to Langone and colleagues (1999) a simple multimedia computer-based instruction program can be used to establish match-to-sample skills, as well as subsequent generalization of those skills to the natural setting for students with moderate to severe mental retardation. Using photographs of cereal boxes as part of an interactive multimedia tutorial, Langone and his colleagues increased the likelihood that selection of specified cereal boxes would generalize to the grocery store in the community.

Other studies have employed media, including video illustrations, to serve as training illustrations for understanding, application and subsequent use in the classroom or community setting (Mechling, Gast, & Langone, 2002; Morgan & Salzberg, 1992). The outcome reported by Haring et al., (1995) and others is that individuals with intellectual disabilities can learn skills via rich media-based illustrations in one setting that will generalize to another setting (e.g., community, home).

Finally, Lieber and Semmel (1989) conducted a study to examine whether grouping students impacted social and instructional interaction between children with disabilities and their typically developing peers. The purpose of the study was to compare social and instructional interaction, by way of microcomputers, based on group configuration and alterations to task difficulty. Although the primary focus was not on inclusive practices, per se, the findings from this study have implications with regard to the potential role that technology can play in promoting inclusive practices for students with mental retardation. Lieber and Semmel found that when paired with typically developing peers with the use of computer technology as the focal point, children with intellectual disabilities were more likely to interact with peers, make positive self-evaluation statements, and make negative peer-evaluation statements.

Employment

Employment is an area of both importance and dependency for people with intellectual disabilities, and technology use has become an increasingly important way to support them to gain and maintain employment. In 1987, Gaylord-Ross identified the use of instructional technology as an important element in successful supported employment efforts. While the use of technology for job training and job skill development, as emphasized by Gaylord-Ross, is still important, the emphasis in this functional area has grown to include the use of technology to provide on-the-job supports and real time assistance to workers with intellectual disabilities. In addition, technology is being used to teach complex job related skills that do not pertain to a specific task or activity, but rather the acquisition of positive behavioral and social skills necessary for successful employment (Storey & O'Neil, 1996; Morgan & Salzberg, 1992).

More recent examinations of technology use to improve vocational outcomes for individuals with intellectual disabilities have generally addressed two areas; improvement of specific job task performance while minimizing human supports from others (i.e., job coaches, supervisors) and improvement of social and behavioral skills related to work settings. Such applications of technology have generally yielded positive vocational outcomes (Barkvik & Martsson, 2002; Davies, Stock & Wehmeyer, 2002a; Mitchell, Collins, Shuster & Gassaway, 2000; Taber, Alberto & Frederick, 1998).

Teaching appropriate job-related social skills is an area where technology has been applied to support workers with intellectual disabilities. Mitchell and colleagues (2000) taught three students with mild intellectual disabilities to use a cassette recorder as an auditory prompting system to assist with a variety of vocational skills in a middle school. The ability of the students to learn to operate the recorder and follow the instructions was assessed, as well as the ability to generalize the acquired skills to another setting. In addition, effects on skill maintenance were assessed. Students were taught how to turn on the cassette recorder, listen to the auditory instructions while wearing headphones, and to turn off the cassette recorder after listening to the instruction and hearing a beep. Students were instructed to verbalize the step and then perform it. A multiple probe across behaviors design was used and the results demonstrated that students were able to acquire the targeted skills and that the skills did transfer to another setting.

In another study, a portable cassette recorder with step-by-step recorded prompts was used to evaluate the utility of a self-operated auditory prompting system with five school-age workers with moderate intellectual disabilities using prompts delivered in one-word or multiple word instruction segments (Taber, Alberto, & Frederick, 1998). Instructions were presented in a to-do list format. Subjects were taught to press the play button to listen to the task, and then stop the recorder in between tasks. The number of successful transitions from one task to another measured task performance, as subjects had demonstrated great difficulty moving from one task to the next independently in baseline sessions. Results showed significant improvement in the ability to change from one task to the next when using either the single or multiple word auditory prompting system. There were no significant differences found when comparing the single and multiple word auditory prompting approaches.

Computer-based prompting devices with specialized interfaces have been applied to support vocational tasks. Davies, Stock, & Wehmeyer (2002a) evaluated the impact of a handheld computer based system designed to provide self-directed audio and picture prompts on improving task accuracy and independence in accomplishing two different vocational assembly tasks, folding pizza boxes and packaging a commercial software product. Ten adolescents and young adults with intellectual disabilities performed each task with and without the presence of the technology system. Results indicated that the computerized prompting system significantly improved task performance. In addition, these gains were achieved with significantly greater independence, as measured by the amount of assistance required from a job coach to complete each task. In addition, subjects expressed positive reactions as well as preference for using the specialized prompting system.

In addition to technology applications for providing self-directed prompting to facilitate task performance, research has also addressed use of technology to promote time management in vocational settings. Davies, Stock and Wehmeyer (2002b) described a software program running on a palmtop computer that can be used by supervisors, job coaches or educators to create a picture and audio-based scheduler that can be programmed to prompt users on specific vocational activities at a particular time or according to a pre-defined schedule of activities. At the prescribed time, the handheld computer turns itself on and alerts the student to the activity using a combination of audio and visual alarms, a picture cue representing the event, and personalized audio messages describing what the individual needs to do at the particular time. Study participants were required to initiate a number of tasks at specific times. An error was recorded if the individual failed to initiate the activity at all, if he or she did not initiate the activity within one minute of the scheduled time, or if the activity was initiated too early. Results showed significant improvement in the ability to initiate tasks on schedule in response to the prompting system as compared to baseline data.

Although studies of the application of technology in supported employment have been sparse, extant evidence suggests that technology systems, particularly those designed to address support and user interface needs of individuals with mental retardation, can improve vocational outcomes for many individuals. These outcomes can also be sustained over time, as demonstrated by Mann and Svorai (1994). Their project demonstrated successful placement of 17 of 27 persons during a three-year demonstration project of individuals who had utilized a computer training system to learn skills necessary to retain basic computer jobs.

Recreation and Leisure

Applications of technology to the area of sports, recreation, and leisure skills has considerable promise to improve the quality of life of students with disabilities (Cain, 1984). Being able to fill spare time in purposeful ways is important to one's quality of life. Recreational programming of age-appropriate skills can help to bridge the gap between students with and without disabilities for inclusion in community settings (Sedlak, Doyle & Schloss, 1982).

Toy use by children with intellectual disabilities has been studied extensively. Particularly for young children with multiple cognitive and sensory disabilities, toys using switches and other technologies encourage play, motivate movement, and support cause-effect learning. Switches are simple and intuitive, and can be mastered with low physical effort (Bailey, 1993). Behrmann, Jones, and Wilds (1989) suggested that technology can benefit young children to encourage learning, recreation, and life skills. In fact, various sensory modalities can be encouraged by technology use: Visual sensory input can be supported by flashing and blinking light toys; auditory input by tape recordings, music, sounds; and tactile input through use of vibrating toys. There has been some discussion of the motor skills (i.e., range of motion, press and release), visual perceptual skills (i.e., visual tracking, figure ground), cognitive or language skills (i.e., cause and effect, attention span that is sustained and selective, object permanence, making choices), and social skills (i.e., turn taking, following one-step directions) needed for initial switch or technology use (Behrman et al., 1989). However, these skills can be supported in young or less capable individuals to encourage participation for technology use.

Research also shows that older students with intellectual disabilities can benefit from use of microswitch technologies. In a multi-component study by Kennedy and Haring (1993), recreational stimuli were used to provide a contingency for choice. Participants used microswitches to request a change related to recreation, and the use of this technology increased the level of alertness and response to interactions by children and adolescents with intellectual disabilities in school settings.

Computer or video games provide age-appropriate, socially acceptable opportunities to both participate in preferred leisure and recreation activities and learn a number of cognitive and eye-hand coordination skills. Sedlak, Doyle, and Schloss (1982) investigated the ability of three adolescents with severe intellectual disability to learn to play a popular video game and generalize this skill to a community setting. Two of the three students were able to accomplish these objectives with a minimum of instruction and follow-up. Obviously, the nature of computer and video games has changed dramatically since this study was conducted, and there is a need for more current information about this use of technology by students with intellectual disabilities.

In another study, leisure skills, including playing cards, selecting a television program, playing a sports videotape, and playing a computer game, were taught to four secondary students with intellectual and motor disabilities (Collins, Hall & Branson, 1997). During generalization these students were able to perform the tasks with little prompting as monitored by peers without disabilities. Increased interaction with non-disabled peers was also supported through the students' mutual interest in the technology applications.

The World Wide Web has become a source of recreation and leisure for many people. Barriers for students with intellectual disability to use the Web include limited opportunities to use computers, lack of appropriate and cognitively accessible Internet-access software, and the complexity of computer operating systems and amount of reading required. Davies, Stock, and Wehmeyer (2001) examined a prototype Web browser, Web Trek (AbleLink Technologies), which was designed to provide access to the Internet for individuals with cognitive disabilities. The performance of 12 adolescents and young adults with intellectual disabilities was compared on two browsers – the Web Trek and Microsoft's Internet Explorer. Measuring independence, accuracy, and task completion, participants showed significantly more success using the Web Trek browser. The Web Trek was able to reduce screen clutter to minimize confusing symbols, could be personalized to support user's preferences, used pictures and audio prompts rather than text-based directions, and supported error minimization to support universal design for access.

Recreational pursuits such as exercise and physical fitness have also been supported with the use of technology. A study by Stanish, McCubbin, Draheim, and Mars (2001) measured the effects of leader support to facilitate engagement in moderate to vigorous physical activity related to aerobic dance with 17 adults with intellectual disabilities. The program was video-based and lasted 10 weeks. Participants were divided into two groups, one that had an exercise leader. Through the video-based exercise activities, people with mental retardation were able to engage in recreational activities that also would lead to improved health. Douglas, Douglas and Hett (1989) used technology to provide reinforcement for a 14-year-old student with moderate levels of intellectual disabilities to ride a stationary bike so that a minimum amount of teacher supervision was required for exercise to occur. Of the three conditions (i.e., television, flashing lights, or vibrator sound), the most effective reinforcing consequence for the student's exercise behavior was vibrator sound. Another instance of exercise management was a study completed by Ellis, Cress and Spellman (1992) that used a digital kitchen timer and an adapted lap counter to facilitate self-management of exercise for five students with intellectual disabilities.

Conclusion

There is only limited information about the use of technology by students with intellectual disabilities, and while there is a need for more such efforts, there is sufficient evidence that students with intellectual disabilities can benefit from technology across multiple domains. The extant literature base has a bit of a "let's see if they can use it" feel with regard to the application of technology solutions for students with intellectual disabilities. In most cases, there is little or no evidence that the technology evaluated was designed to take into account issues of cognitive accessibility. There needs to be more research examining the impact of universal design features on technology use by students with intellectual disabilities, not so much to evaluate whether or not students can use the technology, but instead to investigate what design features can, in fact, ensure such use and benefit. Considering the characteristics of learners with intellectual disabilities, such as those discussed in this article, is important both for research and for technology design. In the meantime, however, teachers should use information about student characteristics and universal design features to evaluate and select technology that will maximally benefit students with intellectual disabilities.

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Creating a Technology Toolkit for Students with Mental Retardation: A Systematic Approach

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Assistive technology consideration and implementation is often limited by the technology experience and knowledge of the education professionals involved in the process. The creation of a toolkit containing highly useful technologies may assist education professionals in this process. This article discusses a systematic method for creating a technology toolkit for use with students having mental retardation. Implications and future directions are discussed.

In 1991, the Association for Retarded Citizens (ARC) of the United States issued a position statement stating that assistive technology (AT) could be a useful tool for individuals with mental retardation. The Division on Mental Retardation and Developmental Disabilities of the Council for Exceptional Children published a position statement recognizing that "persons with mental retardation and developmental disabilities at all age levels and across cultures may benefit for assistive technology devices and services" (Parette, 1997, p. 267). In the same year, the 1997 Amendments to the Individuals with Disabilities Education Act mandated that educational teams must consider AT for all students enrolled in special education [29 U.S.C. 2201, §3(1)]. Despite much subsequent professional discussion regarding AT service delivery (see Bryant & Bryant, 2003; Edyburn, 2000b, 2001, 2002; Institute for Matching Person and Technology, 2004; Judge & Parette, 1998; King, 1999; Zabala, 2002), professional understanding of the process of considering and providing AT remains uneven.

Several frameworks have appeared in the literature to assist education professionals in creating effective matches between the needs of students with disabilities and technology that may help students with disabilities to be successful in the school environment (Bowser & Reed, 1995; Chambers, 1997; Melichar & Blackhurst, 1993; Institute for Matching Person and Technology, 2004; Zabala, 1995; 2002). Each of these frameworks requires education professionals to react to individual student issues by identifying characteristics of the student and environment that may impact the student's ability to do expected educational tasks, and make decisions regarding potential AT solutions.

However, though such frameworks for making AT decisions continue to be implemented nationally, many education professionals do not feel they have the knowledge and skills to effectively identify AT solutions (Anderson & Petch-Hogan, 2001; CEC Today, 1997; Derer, Posgrove, & Reith, 1996; McGregor & Pachuski, 1996; Edyburn 2004), and both teachers and students often do not have ready access to AT devices and materials (Thompson, Siegel, & Kouzoukas, 2000; Wehmeyer, 1998, 1999). This can result in teacher, administrator, student, and family frustration that can compromise the willingness of teachers to integrate AT into the curriculum (Lahm, Bausch, Hasselbring, & Blackhurst, 2001; Lesar, 1998; National Council for Accreditation of Teacher Education, 1997), and potentially have consequent long-term detrimental effects for students with mental retardation.

To facilitate the process of AT decision-making, educational professionals must have access to resources to increase (a) awareness of potential technology solutions, and (b) understanding of characteristics of potential technology solutions to make appropriate matches to meet students' needs. Both the Apple Classrooms of Tomorrow Studies (1991) and the Milken Family Foundation (Lemke & Coughlin, 1998) reported that teachers must have core knowledge of the functions and characteristics of technology before effectively teaching others how to use it or integrate it into students' educational programs. Once teachers have an understanding of AT characteristics and functions, they need to match the technology to meet their students' needs.

One effective approach is a feature match process (Costello & Shane, 1994; Glennen 1997; Yorkston & Karlan, 1986) that requires teachers to (a) be knowledgeable about the operational and learning requirements of possible AT solutions (Beukleman & Mirenda, 1998); and (b) understand the extent to which each potential AT solution places cognitive, linguistic, physical and time demands upon the user (King, 1999). Such understanding allows teachers to make practical decisions regarding AT that can be used to assist a particular student.

The AT Toolkit Approach

One promising solution to assist educational professionals in effective AT consideration and implementation that has been reported by Edyburn and Gardner (1998) is the concept of an AT toolkit. Edyburn (2000) has described an AT toolkit as a collection of tools that (a) is targeted to meet the performance demands of a given population, (b) focuses on appropriate tools to enhance a user's performance rather than on the cost of a piece of technology, (c) effectively allows educational professionals to make informed choices from a set of probable tool solutions rather than an overwhelming set of products available on the market, and (d) is portable and readily available for the use in the classroom.

An AT toolkit is a proactive strategy to assist in meeting the needs of students with disabilities by allowing the technologies within the toolkit to be quickly placed in the hands of both teachers and students fostering exploratory use (Edyburn, 2000). Through exploration, assessment data can be gathered relating to the technology's effectiveness. Edyburn and Gardner (1998) noted that potential outcomes of an AT toolkit may include: (a) improved participation of more students, (b) increased IEP team knowledge of potential AT tools for a given population, (c) greater frequency of considerations of AT tools as solutions for students with disabilities, (d) heightened interest in new AT solutions that may better meet the needs of a particular students, and (e) additional information about how a student interacts with an AT tool that may allow for a more specific device-feature match. Edyburn (2004) noted:

> The process of developing an assistive technology toolkit could be an invaluable contribution to the profession and could significantly enhance the educational performance of students with mild disabilities…the assistive technology toolkit would allow teachers to collect performance data regarding the value of specific tools for individual students. (p. 13)

While the AT toolkit approach may hold promise in the consideration and implementation of AT for students with disabilities, particularly students with mental retardation, little has been done to develop a method for the systematic construction of a toolkit for a specific population. Several toolkits have been proposed in the literature based on individual experience in working with students with disabilities (Fenema-Jansen, 1998; Holt & Edyburn; 1998; Kaplan & Edyburn, 1998). Similarly, numerous examples of toolkits used by specific groups are presented on Web sites (cf, Hampshire Educational Collaborative, 2002; University of Kentucky Assistive Technology Project, 2003; Williamsville Central School District, 2001).

Unfortunately, there is little available evidence of background development activities that provide a sound foundation for the creation of AT toolkits. Watts, et. al. (2003, 2004) proposed a method to systematically create an AT toolkit and offered a preliminary toolkit targeted for students with developmental disabilities. Basically, this approach involved soliciting tool suggestions from teachers in the field about useful technologies for particular groups of students and then ranking the suggested list from most useful to least useful. This process would culminate in a final sorted list that provides a field-based, practitioner-supported foundation for the creation of the toolkit.

The remainder of this article extends the work previously reported by Watts, Thompson, and Wojcik (2003, 2004), but focuses specifically on the creation of a toolkit designed for use with students with mental retardation.

Method

A modified Q-sort methodology was used in the study, employing a two-phase process to identify key AT devices for inclusion in the toolkit. Basically, the process involved developing statements from experts (a Q sample) that were administered to other participants in the form of a Q sort with subsequent rankings of cards containing specific statements (Brown, 1991; McKeown & Thomas, 1988). Phase 1 involved the collection of input from participants identified as having substantive experience working with students with mental retardation and use of effective technologies used with students having mental retardation. Phase 2 involved the sorting process that resulted in a prioritized group of technologies that could be used with students with these students.

Phase One

Participants

Participants in Phase 1 included professionals drawn from a pool of nominations ($n=10$) made by local special education directors and teachers in a urban school district in central Illinois. Persons nominated had to meet two criteria: (a) substantive experience working with students with mental retardation, and (b) expertise with both instructional and AT within the school setting. The participants' experiences working with students with mental retardation ranged from 8 to 17 years. The participant pool included 7 teachers, 2 speech-language pathologists, and 1 occupational therapist.

Instrumentation

A survey instrument was used to collect data in Phase 1. The survey contained a list of technology categories and corresponding definitions for each category. Table 1 presents the technology categories and definitions used in the survey. The categories and definitions used in the survey were taken

Table 1.
Assistive Technology Categories and Descriptions

Category	Definition
Communication	Products and equipment designed to help persons with speech, mental retardation, or writing difficulties to communicate. At its simplest, augmentative communication can be a page with picture choices or alphabet letters that a person points to. It can also involve highly sophisticated speaking computers with on-screen communication boards and auditory or visual scanning.
Computer Access	Hardware and software products that enable persons with mental retardation to access, interact with, and use computers at home, work, or school. Includes modified or alternate keyboards, switches activated by pressure, touch screens, special software, and voice to text software.
Daily Living	Self-help devices that assist persons with mental retardation in daily living activities such as dressing, personal hygiene, bathing, home maintenance, cooking, and eating.
Mobility	Products that help mobility impaired persons move within their environment and give them independence in personal transportation.
Recreation	Products that help persons with mental retardation to participate in sports, social, cultural events.
Reading	Products that help persons with mental retardation access and understand print.
Writing/Spelling	Products that help persons with mental retardation communicate through writing in a way that they can be understood.
Math	Products that assist persons with mental retardation to perform mathematical calculations.
Memory and Organization	Products that assist individuals with mental retardation to perform activities that may include the organization of materials, remembering sequences of steps, and operating within a schedule.

from published technology taxonomies (Abledata, 2004; Rehabtool; 2004). The survey instrument asked participants to make suggestions regarding tools that they had found very effective in working with students of mental retardation in the school setting.

Procedure

After participants were identified, each was mailed a copy of the survey instrument and asked to complete and return it. Once the survey instruments were returned, tools identified by the participants were aggregated by categories. A second survey instrument containing the aggregated tools was then sent back to the participants. The participants were asked to (a) review the previously suggested tools and (b) add any other suggestions pertaining to additional tools that might be included in each category. After the second survey instruments were returned, a list containing all of the suggested tools was compiled. The final list contained 77 items that the participants felt were useful in working with students with mental retardation.

Phase Two

Participants

Participants (n=43) were recruited from local school systems within central Illinois and from Illinois State University graduate classes. Participants identified themselves as having experience working with students with mental retardation. Years of experience in working with students with mental retardation ranged from 2 to 29 years. Persons included in the participant pool included 41 special education teachers, 1 school psychologist, and 1 speech-language pathologist.

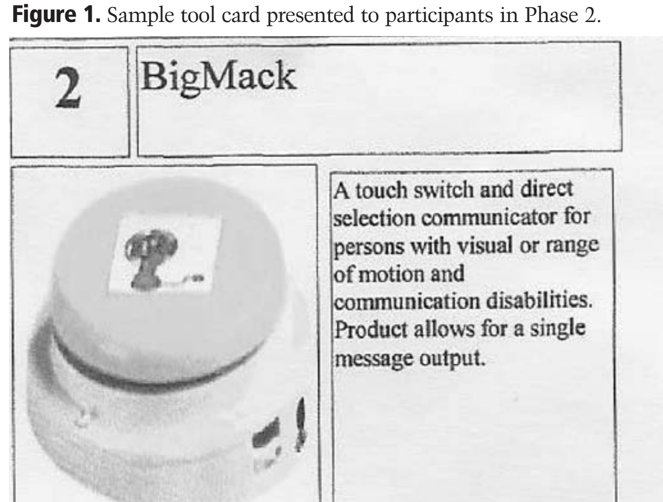
Instrumentation

The final compiled list of suggested tools from Phase 1 became the list of tools used in Phase 2. Cards were created using this list of tools, with each card containing the name of the tool, a brief description relating to the function of the tools, a picture of the tool, and a code number (see Figure 1). In addition to the cards, a record sheet was developed containing a table with 11 columns and 77 cells distributed across the 11 columns. The label over the left-most column was *Least Useful* and the label over the right-most column was *Most Useful*.

Procedure

Phase 2 was held in three sessions with each session containing a different group of participants totaling 43

Figure 1. Sample tool card presented to participants in Phase 2.



participants. Each participant was given the stack of cards (as described above) and a record sheet. The participants were asked to review all of the cards in the stack. The participants were then asked to sort the cards on a continuum from least useful to most useful with regard to working with students with mental retardation in the school setting. The participants were asked to rank relative utility based on a spectrum of students with mental retardation ranging from mild to severe, and from 3 through 21 years of age. Participants were also instructed to ignore cost as a factor in sorting the cards. It was recommended that the participants begin sorting the cards at the extremes of the continuum and then work toward the midpoint. Once the cards were sorted, the participants were asked to record their sort by placing the code number of each card in the corresponding position on the record form. The cards and record forms were collected at the end of each session.

Results

After the second phase of the study, the data from each of the record forms was placed into a statistical program for analysis. Each item was coded based on position on the continuum and was assigned a value from one (least useful) to eleven (most useful). Means were then calculated for each of the 77 items and the means were placed in an ascending list (Range = 2.52 -9.05). Value points were then calculated to separate the list of tools that were placed into quintiles. Low-utility tools (n=9) included such solutions as sock aids, collapsible canes, scooter boards, and card holders. Moderately low-utility tools (n=11) included such solutions as key guards, battery adapters, lap trays, and adapted can openers. Moderate-utility tools (n=25) included such solutions as on-screen keyboards, computer switch interfaces, Franklin Spellers, and tape recorders. Moderately-high utility (n=22) included such solutions as the Big Mack, Big Keys Keyboard, Touch window, and Dynamite. High Utility tools (n=10) included such solutions as books on tape, communication boards, visual schedules, and Intellikeys keyboard. The specific results are summarized in Table 2.

Discussion and Implications

The results presented interesting findings regarding the nature of the tools that participants ranked as most useful for working with students with mental retardation in school settings. The four categories of AT, deemed to be of greater utility for these students, and were supported by research in the field: (a) communication (Glidden & Abbeduto, 2003; Iacono & Miller, Romski, Sevcik, & Adamson, 1999); (b) computer access (Davies, Stock, & Wehmeyer, 2001, 2002); (c) access to print (receptive and expressive, Hoppenhaver & Pierce, 1994; Parette, 2004); and (d) behavioral regulation (Bambera & Ager, 1992; Keyes, 1994).

Other categories of AT viewed as having less utility included tools for (a) mobility and positioning, (b) recreation, and (c) aids for daily living. However, since the original pool of tools was created by individuals who had substantial experience working with students with mental retardation and AT, all of the tools could be seen as both viable and practical tools for these students in school settings.

The AT toolkit presented here can be used as a guide to assist education professionals in making decisions about assistive technology to assist students with mental retardation. First, the toolkit allows educational professionals to make decisions about the order in which AT may be purchased subsequent to effective planning processes. Second, once a toolkit is assembled, education professionals will have ready access to the tools to allow them to develop skills and knowledge about each of the tools through hands-on experience. This assumes, however, that appropriate training is available to familiarize teachers with best practice usage of the tools in the school curriculum (Parette, VanBiervliet, & Wojcik, 2004). With the growth of the field of AT in recent years, coupled with the IDEA mandate that AT must be considered when developing individual education programs (IEPs), there has been increased need for use of interdisciplinary teams to conduct AT evaluations and make decisions about AT solutions. As noted by Edyburn (2004), this mirrors special education processes (e.g., multidisciplinary team evaluation, extensive in-depth evaluation, team meeting, recommendations) while presenting challenges that include (a) commitments of staff time, (b) intimidating environments for family members asked to participate in meetings with professionals, (c) commitments of resources to initial evaluation vs. on-going follow-up or support, and (d) difficulties in scheduling frequent or timely meetings. Teachers, particularly those in general education settings, often see themselves as novice users of AT and may see less purpose in including technology in instructional processes, while those with more advanced training are typically more positive toward AT integration (Weber, Schoon, & Forgan, as cited in Anderson & Petch-Hogan, 2001). Training teachers to increase literacy proficiency using AT is particularly important given the impetus of the No Child Left Behind Act (P.L. 107-110), that (a) requires states to develop curriculum standards, (b) requires development of assessment systems to measure student performance in meeting the standards, (c) emphasizes reading attainment by grade 3, and (d) sanctions low-performing schools (Edyburn 2004). The need for assisting teachers to utilize AT to develop literacy skills is also reflected in the current national impetus toward outcomes measurement as demonstrated through NIDRR funding of two prominent national projects (Assistive Technology Outcomes Measurement System, 2004; Consortium on

Table 2.
Ranking of Relative Utility of Tools for Students with Mental Retardation

Rank	Tools	Vendor Website, if applicable
High Utility	Books on Tape	
	Communication Boards	
	Visual Schedules	
	Writing with Symbols 2000	www.mayer-johnson.com
	Go Talk	http://www.attainmentcompany.com/
	Speaking Dynamically Pro	www.mayer-johnson.com
	Line Drawings/Symbols	
	Intellikeys Keyboard	www.intellitools.com
	Social Story	
	Speech Recognition	
Moderately High Utility	Big Mack	www.ablenet.com
	Big Keys Keyboard	www.keyalt.com
	Touch Window	
	Dynamyte	www.dyanvoxsys.com
	Time Timer	www.timetimer.com
	Intellitalk II	www.intellitools.com
	Write:Out Loud	www.donjohnston.com
	Specialized Calculators	http://www.attainmentcompany.com/
	Enlarged Print	
	Picture Recipes	
	Intellipics Studio	www.intellitools.com
	Visual Assistant	www.ablelinktech.com
	Clicker 4	www.cricksoft.com
	Object Schedules	
	Talking Calculator	
	Raised Line Paper	www.pfot.com
	Track Ball	
	Talk Trac Plus	www.ablenet.com
	Picture Cue Cards	
	Kidspiration	www.inspiration.com
	Co:Writer	www.donjohnston.com
Moderate Utility	On Screen Keyboard	
	Computer Switch Interface	
	Intellimathics	www.intellitools.com
	Step By Step Communicator	www.ablenet.com
	Reading Ruler	
	Draft: Builder	www.donjohnston.com
	Slant Desk	
	Franklin Speller	www.franklin.com
	Operating System	www.microsoft.com
	Accessibility Options	www.apple.com
	Tape Recorder	
	Alphasmart	www.alphasmart.com
	Number Line	
	Counters	
	Dycem	www.sammonspreston.com
	Utensil with Universal Cuff	www.sammonspreston.com
Moderate Utility (cont.)	Pencil Grips	
	Time Pad	www.attainmentinc.om
	Velcro Shoe Laces	
	Highlighter	
	Step Pad	http://www.attainmentcompany.com/
	Adapted Seating	
	News-2-You	www.news-2-you.com
	Name Stamps	
	Motion Pad	http://www.attainmentcompany.com/
	Post It Notes	www.postit.com
Moderately Low Utility	KeyGuard	www.infogrip.com
	Power Link/Battery Adapter	www.ablenet.com
	Talking Picture Frame	www.radioshack.com
	Voyager Desk Top Suite	www.ablelinktech.com
	Lap Tray	
	Movin Sit	www.sammonspreston.com
	Uni Turner	www.sammonspreston.com
	Adapted Can Opener	www.sammonspreston.com
	Foam "Builders" for Adapting Utensils, etc.	www.sammonspreston.com
	Large Foam Rubber Dice	
	Swivel Cushion	www.sammonspreston.com
Low Utility	Sock Aide	www.sammonspreston.com
	Collapsable Cane	www.sammonspreston.com
	Scooter Board	
	Reacher	www.sammonspreston.com
	Toothpaste Dispenser	www.sammonspreston.com
	Card Holders	www.sammonspreston.com
	Bowling Humps	www.sammonspreston.com
	Velcro Dart Set	www.sammonspreston.com
	Card Shuffler	www.sammonspreston.com

Assistive Technology Outcomes Research, 2004). The experiences working with the tools may help education professionals create more effective matches between students and AT as a result of heightened understanding of the feature-match process (Edyburn & Gardner, 1998). For example, King (1999) suggested that professional involvement in 25-50 AT evaluations may be necessary for professionals to develop the requisite understanding of an informed, feature-match process.

Finally, an assembled toolkit will allow students with mental retardation immediate access to the curriculum (Gardner & Edyburn, 2000; Okolo, 2000). For example, numerous software programs identified by participants in this study, including *Writing with Symbols 2000* (Mayer-Johnson), *Go Talk* (Attainment Company), and *Speaking Dynamically Pro* (Mayer Johnson) provide students with mental retardation with meaningful experiences in accessing the curriculum and participating in classroom activities more effectively.

Of particular importance to many education professionals is the opportunity afforded by AT toolkits to complement the formative assessment process. Formative assessments typically are used to track student progress and provide the basis for informed teacher decision-making (Center for Applied Special Technology, 2004). Since formative assessments are generally instructionally based and ongoing, student performance during an instructional activity may be monitored so that education professionals can implement needed AT interventions before students fail (Edyburn, 2002; Parette, 2004).

This study is limited, however, in several ways. The tool list developed in Phase 1 of the study was elicited from a relatively small pool of individuals serving students with mental retardation in central Illinois. Although participants were selected who had substantial experience working with students with mental retardation and AT, the technologies identified by these individuals may have been bound by their personal experiences. Such experiences may be limited due to a number of factors, including geographic proximity to other participants and/or similar professional development opportunities in AT decision-making and implementation processes. Also, given that the participants in both phases of the study have been working in the field for a range of years, the extent to which they were familiar with recent developments that may assist students with mental retardation is unknown. Consequently, recent technologies introduced in the market may not have been included within the contents of the final toolkit.

There are several implications for future research. Replication is needed to establish the stability of the toolkit's contents (i.e., Do the contents of the kit meet the needs of students with mental retardation across time and settings?). Further investigation may also examine how new and recent technologies may be incorporated into the toolkit approach, and how these emerging technologies gain favor with education professionals. More specifically, the use of AT toolkits must be examined in the context of outcomes, both for education professionals and for students. While there are three significant groups currently focusing their efforts on understanding AT outcomes that may be considered (Assistive Technology Outcomes Measurement System, 2003, Consortium on Assistive Technology Outcomes Research, n.d.; National Assistive Technology Research Institute, 2003), specific recommendations for educational professionals regarding teacher and student AT outcomes have yet to be clearly defined and implemented nationally (Parette, 2004). Possible student outcomes might include (a) increased participation in the general education curriculum, (b) change in academic performance, (c) student satisfaction with the AT device, and (d) student quality of life measures (ATOMS, 2004). Potential teacher outcomes that might be examined could potentially include the (a) occurrences of AT consideration in student-centered planning, (b) integration of AT into educational programs of students with mental retardation, and (c) use of AT in measurement of students' educational progress and in district and state assessments (Wojcik, Peterson-Karlen, Watts, & Parette, 2004). Additionally, as noted by Wojcik et al. (in press), case-study based repeated measures of performance should also be developed to measure progress of teachers using the toolkit toward proficiency and application of AT knowledge and skills.

Measuring educational and social outcomes for K-12 students with mental retardation subsequent to toolkit usage may include examination of (a) extent of AT integration into academic, vocational or life skills instruction, (b) changes in student performance, (c) extent and nature of participation with typical peers, (d) participation and performance in state and district assessments, (e) quality of life, and (f) the changes in intensity of supports needed by the student to achieve independent (Wojcik et al., in press). Interestingly, though books on tape were noted as being of high utility, books on CD played using MP3 players might be more socially acceptable and preferred by students (Parette, 2004; Zabala, personal communication, April 2, 2004). Many decisions about AT for students with mental retardation are made without a clear understanding of the influences of peers and acculturation influences (Parette, 2004; Parette & Scherer, 2004; Parette, Huer, & Scherer, 2004).

Toolkits, once developed and assembled using such a systematic approach described in this article, may be implemented by education professionals in classrooms serving students with mental retardation. The inherent value of developing and implementing AT toolkits is that education professionals may monitor the usage of specific devices contained in the kits and gain insights regarding student preferences for devices contained in the kits. Similarly, it affords education professionals experience in matching device features to particular students, as well as providing opportunities to implement, integrate, and evaluate the toolkit solutions available in the classroom.

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Computer Assisted Instruction to Teach Item Selection in Grocery Stores: An Assessment of Acquisition and Generalization

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The purpose of this study was to evaluate the effectiveness of a computer-based program designed to increase percentage of correct match to sample discrimination tasks and generalization of the skills to a natural setting. Four students with moderate to severe intellectual disabilities participated. The dependent variables were: (a) the percentage of correct match to sample trials completed on the computer and (b) the percentage of items correctly selected in the natural setting of a local grocery store. Pre and post generalization testing included locating items presented and not presented during instruction. The independent variable was a multimedia computer program entitled Project SHOP that provided instruction through interactive practice activities incorporating a graduated response criterion. A multiple probe design across behaviors and replicated across four participants was used to evaluate experimental control. Results indicated that following intervention, the percentage of correct response in the community increased.

One principle of applied research is to design intervention programs targeted to teach useful skills to the participants (Baer, Wolf, & Risley, 1968), while structuring the program to promote generalization of the skills to the natural environment (Stokes & Baer, 1977). Proficiency in community skills (e.g., community navigation and shopping skills) allows a person more opportunity to interact independently in his/her environment. For students with significant disabilities, community based instruction has become a curricular focal point. The explicit rationale for community-based instruction is that in vivo training is one of the best methods of teaching functional skills (Cuvo & Katt, 1992). In vivo instruction allows for inclusion of the full range of natural stimuli and distractions that will be present when students need to perform the targeted skills with diverse stimuli and distracters. Since instruction occurs in the actual setting, the probability of generalization across settings increases (McDonnell, Hardman, Hightower, Keifer O'Donnell, & Drew, 1993; Nietupski, Hamre-Nietupski, Clancy, & Veerhusen, 1986).

Frequent in vivo training opportunities may be difficult to arrange because of factors like scheduling and funding for community-based instruction (Wissick, Gardner & Langone, 1999). Teachers, therefore, may need to look for alternative methods to teach functional skills. While, classroom simulations are relatively inexpensive to establish and provide daily opportunities for instruction and practice, they lack the same stimuli and distracters found in the natural setting. Neef, Lensbower, Hockersmith, DePalma, and Gray (1990) found that generalization is more likely to occur when simulated stimuli and activities are similar to the target setting. Even though challenges may arise when trying to facilitate generalization of skills learned in the classroom to the natural environment, pairing in vivo instruction with simulation has emerged as a promising possibility (Morrow & Bates 1999).

Computer software programs can incorporate animation, photographs, and video to represent features of the natural environment, while providing multiple exemplars, immediate feedback, and consistency. For instance Ayres and Langone (2002) used a multiple probe across participants to evaluate effects of computer-based instruction (CAI) employing photos, video, and animations in a simulation to teach students with intellectual disabilities to pay for grocery items. The researchers measured acquisition of the target skill on the computer and then assessed generalization in community-based probes. While they reported changes on the dependent measure on the computer, they failed to see generalization to the community.

However, they reported anecdotal changes in types of errors students made in the community setting before and after intervention: the errors after intervention, topographically, looked more similar to what students had seen in the video.

Closely related to the current study, Wissick et al. (1992) evaluated the effects of an interactive videodisc simulation to teach three students with moderate intellectual disabilities how to locate and purchase items in a grocery store. The dependent variables included the number of extra actions to locate an item, the amount assistance from the teacher required, and the number of purchasing steps correctly completed. The researchers reported a decrease in the amount of teacher assistance and number of extra steps that students took to complete the shopping tasks and after engaging in intervention. These findings translate into increased efficiency and independence for students. In a similar study, Mechling, Gast, and Langone (2002) used computer-based video instruction to teach strategies for locating items in a grocery store to students with moderate intellectual disabilities. Using video embedded in a computer program, the researchers taught students to identify sight words from aisle markers and match those to the items on their list. After acquiring the skill on the computer, the students generalized the strategy to grocery stores.

Mechling and Gast (2003) demonstrated the use of multi-media instruction to teach students with moderate intellectual disabilities to locate grocery items by reading aisle sign words related to the items on the list (i.e., essentially teaching concept classes of food (e.g., brownie mix is found on the aisle with a sign reading cake mix). The CAI included video modeling, text and photographs embedded in a multimedia program and placed within the context of discrete trial instruction with constant time delay. Students acquired the target skills on the computers and successfully generalized the skills to the community setting where they improved their performance on locating items based on aisle markers.

Langone et al., (1999) used CAI to teach functional discrimination skills to four students with moderate/severe intellectual disabilities in middle school. Using photographs embedded in a multimedia program, the researchers created a simulation to teach identity sample matching of cereal boxes on the computer. This was designed to simulate a student using a picture grocery list to locate cereals. Students acquired the skill on the computer and in an evaluation of generalization, the researchers reported that in addition to students accurately locating the cereals, the mean and median durations for students' time searching decreased.

Grocery shopping is a functional skill in which people will participate for the rest of their lives (Morse Schuster, & Sandknop, 1996). Considering that students with intellectual disabilities will need specific instruction in learning the skills required to shop independently or with as little assistance as possible, researchers are encumbered with identifying the most efficient, cost-effective ways for students to learn these skills. Computer programs can provide simulated models of what actually occurs in the natural setting (Stokes & Osnes, 1989). Computer assisted instruction (CAI) can assist students with identifying the relevant stimuli for a situation by making the critical stimuli more salient and delivering instruction via computer allow an unlimited amount of practice any time of the day (Langone et al., 1999). The ability to control multiple exemplars sampling a variety of people, behaviors, settings, and items shown on the videotapes or pictures when using computer programs may assist with generalization by allowing student to encounter a wider range of stimuli than in other classroom simulations (Mechling & Langone, 2000). Well designed CAI brings the student to the center of instruction by requiring them to take active role responding to the real-life scenarios is taking place on the computer screen. Using computers for instruction is age-appropriate for people of all ages (Wissick et al., 1992).

The use of technology may be the answer to providing an effective and efficient strategy to teach students with disabilities functional skills, such as grocery shopping, when extensive community-based instruction is not available. The purpose of this study was to evaluate the effectiveness of a CAI program to increase the percentage of correctly selected grocery store items by the four participants with moderate to severe disabilities to assess their ability to generalize to the natural setting. The dependent variables measured included the percent of correctly selected items, the duration to select each item, and generalization from the CAI to the natural environment.

Methods

Participants

Four students with moderate to severe intellectual disabilities participated in this study (Table 1). All of the participants received special education services in a self-contained classroom in a public middle school. The students had been receiving community-based instruction at least once per week at a grocery store, drug store, or fast food restaurant. None of the students had been engaged previously in systematic instruction to teach item location. Students were selected for this study based on age, disability, having grocery shopping goals in their IEP, the desire of the parents to have their child learn the target skill and provide informed consent, and an average daily attendance greater than 90%. All students had to demonstrate specific prerequisite skills before beginning the study: (a) visual ability to see the computer screen and recognize grocery items, (b) auditory ability within normal range, (c) motor ability to make selections on the computer screen using a mouse or touch screen and in a grocery store, (d) ability to maintain attention to the task for 35 minutes (estimated session length in the grocery store), (e) motor imitation for selecting an item, and (f) waiting 5 to 30 seconds for a prompt.

Abby enjoyed performing daily living skills such as taking care of laundry, washing dishes, and cooking. She could prepare 10 no-cook or microwavable snacks independently. She filed papers according to letter and numbers. Also, she assisted in the school office stapling, hole punching, and copying. She could tell time up to the quarter hour and could count to 50. In regard to computer skills, she could manipulate the mouse to play games during her free time and type her name, address, and phone number.

Kate could read 40 community sight words and identified all letters of the alphabet. She could tell time up to the half-hour and counted up to 50. On the computer she typed her name, address, and telephone number with alternative keyboard and played games during her free time. Kate was diagnosed with a visual impairment and although she occasionally wore glasses, Kate sat with her face approximately 3 centimeters from the computer screen to see text and icons. With her visual impairment, Kate was able to adapt to her environment and locate items on the top shelves at the grocery store. The computer program was adapted with an enlarged cursor to assist Kate with tracking items on the screen.

Sue was proficient in most self-care skills such as brushing her teeth, bathing, and dressing herself. She enjoyed doing laundry and could independently operate a washer and dryer. She used a mouse to make selections on the computer could type her name and phone number. Sue had difficulty with short-term memory.

Brad read on a 2nd grade level and told time up to the half-hour. He was an excellent speller and had neat handwriting. Brad's independent self-care skills included brushing his teeth, bathing, and washing his glasses. He manipulated the computer and Internet very well. He enjoyed playing games on the computer and looking at calendars in his spare time. Brad was the only participant who did not attend general education physical education in addition to adaptive physical education.

Settings and Arrangements

Community setting. Grocery store probe sessions were conducted in a local grocery store within close proximity of the school. These sessions took place during slow shopping times of the day. The classroom teacher worked with the rest of class on other instructional activities unrelated to the study in other parts of the store. Each session consisted of 16 trials where the participant was positioned within 3 meters of the target stimuli by the researcher. The researcher stood approximately 1 meter behind the participant and the reliability data collector stood approximately 3 meter behind the researcher.

Computer and classroom setting. The computer probe (CP) and CAI sessions occurred in the student's classroom at a computer situated along the wall of the classroom. Participants sat directly in front of the computer facing away from the rest of class. The researcher sat to the right of the participant to help maneuver through the computer program. Each participant took turns working at the computer individually with the researcher while the rest of the class worked with the teacher and paraprofessional on functional skills in other areas of the classroom.

Materials and Equipment

The CAI program, called *Project SHOP*, was developed in an authoring program called Authorware 5.2 (Macromedia, 2000). The program worked on a PC computer running Windows 95 or higher with a CD-ROM player. The program contained all of the digital materials for the discrimination tasks: photographs of 33 cereals, 22 canned soups, 21 frozen pizzas and a shopping cart. The photographs appeared on a background picture of shelves or a freezer with shelves. An image of a shopping cart 2 centimeters by 4 centimeters was

Table 1.
Description of Participant

	Age	IQ Measures	Vineland Adaptive Behavior Scales	Other
Abby	14:3	SS: 40	Composite SS: 58	• Proficient in many self help and vocational tasks. • Skilled with mouse use and typing
Kate	15:2	SS: 36	Composite SS: 63	• Sight word reader, some ability to tell time • Required computer adaptations because of visual impairment
Sue	14:7	SS: 43c	Composite SS: 38	• Strong long term memory • Skilled with mouse and typing
Brad	16:0	SS:54c	Composite SS:58	• Some relative strengths in academic skills (writing) • Diagnosed with autism and had a curriculum focused on social skills

Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984)
Kaufmann Brief Intelligence Test
Stanford Binet Intelligence Scale Fourth Edition (Thorndike, Hagen, & Sattler, 1986)

Figure 1. Screen Captures

located in the bottom left corner of the screen to simulate the view one would see when shopping (See Figure 1). The computer program included a cartoon tutor named Shopper Bob. He acted as a narrator, gave task directions, provided corrective feedback, and reinforced accurate responses. In the grocery store 8 centimeter by 10 centimeter index cards with photographs of the target stimuli were used as discriminative stimuli and the students needed no other materials.

Response Definitions and Data Collection

Data were collected during grocery store probe sessions while the computer program automatically collected data during computer probe and instructional sessions. Accuracy of response and duration data were recorded for each trial. In the community probes, a correct response was defined as the student selecting the target stimuli appearing on the shelf or in the freezer independently within 30 seconds of the initial task direction; similarly, in the computer based probes (CBP), a correct response was defined as clicking the correct match appearing on the screen within 30 seconds of the initial task direction. An incorrect response in both probes was defined as selecting an incorrect item in the allotted 30 seconds. A no response was recorded if the participant did not make a selection within 30 seconds of the task direction.

During CAI, participants were able to respond in one of five different ways:

1. Unprompted Correct: a correct response given within the time limit for the stimulus set (see Table 2 for list of time limits)
2. Prompted Correct: a correct response following the model prompt (model prompts were displayed if the student did not respond within the initial time period.
3. Unprompted Incorrect: a response initiated of an incorrect topography performed within in the time limit
4. Prompted Incorrect: an incorrect response occurring after the model prompt
5. No Response: this was scored when the student did not initiate a response within before or after the model prompt.

Experimental Design

A multiple probe across behaviors of items and replicated across students (Tawney & Gast, 1984) was used to evaluate the efficacy of the intervention. Participant behavior was evaluated across three separate conditions and the conditions were introduced in the following order: (a) grocery store probes (GSP) which functioned to assess generalization, (b) CBP which functioned to assess acquisition, and (c) CAI in which the students were exposed to the independent variable.

General Procedures

Sessions occurred four to five days a week with one to three sessions per day depending on the condition. The GSP

Table 2.
Description of Stimuli

	Number of items appearing on the screen	Time to respond correctly (in seconds)
Cereals		
	1	5
	2	5
	4	5
	10 (1shelf)	10
	20 (2 shelves)	20
	27 (3 shelves)	30
Soups		
	1	5
	2	5
	3	5
	4 (1 shelf)	10
	8 (2 shelves)	20
	12 (3 shelves)	30
Pizzas		
	1	5
	2	5
	3 (1 shelf)	5
	6 (2 shelves)	15
	9 (3 shelves)	30

sessions lasted approximately 35 minutes for each participant while the computer probe and instructional sessions lasted approximately 15 minutes. All students received initial GSP and after data for the primary independent variable, locating the items, stabilized or continued to decelerate, students began CBP. Level stability for data was defined by requiring that 80% of the data fell within 20% of the median. All students received the CBP and for each student the same stability requirements were applied. During CAI, the order of introduction for the intervention was determined by stability of data in probes and the ability to schedule sufficient GSP prior to intervention.

The participants were reinforced with verbal praise for following directions and attending to the task at the end of all sessions. The CAI program had a variety of verbal praise statements built into each trial if a correct response was given before or after the prompt. The schedule of reinforcement was a continuous reinforcement schedule. The CBP trials did not contain any reinforcement except for a general praise statement at the end of the session for working hard.

Grocery Store Probes

The purpose of generalization testing with the GSP was to assess whether the skills taught by the CAI program generalized to the natural setting. Evaluations were conducted through pre and post testing in a grocery store not familiar to the participants. The natural setting had many more distracters, such as shoppers, additional products, and advertisements on floors, freezer doors, and shelves that potentially could have made the task of matching to sample more difficult. Besides being in a different environment than the classroom, participants had more items from which to make a selection. Also, GSP included novel stimuli that were not presented during CAI in addition to stimuli the participants had seen in the CAI sessions.

Grocery store sessions occurred at least three times for all participants before CAI began and after criteria was met for pre and post testing. The specific schedule for the presentation of the conditions was two generalization sessions followed by three computer probe sessions and then one generalization session. The CBP sessions were conducted between the generalization sessions to make sure the probe sessions did not effect generalization testing. There were 32 trials per session for all participants. The 32 trials included 12 cereals with 4 being novel (i.e., not presented during computer probe or instructional sessions), 12 canned soups (4 novel), and 8 frozen pizzas (4 novel).

After the researcher positioned the participant 3 meters from the target stimuli, she handed the picture of the item to the participant and as an attention cue said "What cereal is this?" After the participant's response, the researcher said, "Find same." The participant had up to 60 seconds to locate the item and make a selection by grasping, touching, or pointing to the target item, although the response was scored as correct, incorrect, or no response after 30 seconds. While many items came in multiple sizes the participant was able to select any size item as long as the brand of the product was identical to the picture in order to score a correct response. Correct responses resulted in the item being put in the shopping cart while incorrect responses were put back on the shelf or ignored. A correct response was locating and selecting the target item within 30 seconds of the task direction. An incorrect response was selecting the wrong item. A no response was recorded when no selection was made after 30 seconds of the task direction. If the participant did not respond within 60 seconds, the researcher said "Let's try another one" and started the next trial. There was a five-second interval between items of the same class. The next trial began when the participant was positioned in a new spot 3 meters from the next target item. All of the cereals were tested before moving to a different aisle with another class of products such as soups or pizzas. The same procedures were followed for the other products. A 60 second transitioning time was allowed to move to a different aisle to test another class of products.

Computer Probe Procedures

The purpose of the CBP sessions was to assess the participant's ability to perform the skills on the computer before beginning CAI and then after the instructional criteria were met, to make sure the results maintained without the reinforcement and instruction provided in CAI. Probe sessions were conducted with one participant at a time. The researcher sat next to the participant to help maneuver through the computer program. Each probe session included 10 trials per class of item for a total of 30 trials per session. All items appearing during CBP sessions were targeted during CAI. Sessions lasted until three consecutive sessions of stable or decelerating data were recorded. Stability was defined as 80% of the data falling within a 20% range. Once stability was obtained, the CAI was implemented.

During computer probe sessions, the screen showed 3 shelves of cereals, soups, and frozen pizzas so the maximum number of each item was shown. The number of items appearing on the screen varied according to the size of the photographs. A full screen for each of the different classes of items included 27 cereals, 12 soups, and 12 pizzas. A photograph of the item appeared in the top left corner of the computer screen. Screenshots of the 3 different computer probe displays are shown in Figure 1.

Sessions began with the task direction: "Click on the item that matches the item in your flipbook." The participant had 30 seconds to locate the target item and click on the item using the mouse or touching the item if using a touch screen. When the student made a correct selection, the item moved into the shopping cart in the bottom left corner of the screen and the next trial began. The student received no verbal praise for correct responses during CBP. The computer ignored incorrect and no response errors and immediately began the next trial. Each session consisted of 10 trials from each of the three stimulus sets.

Computer Based Instruction

During CAI sessions the computer displayed photographs of grocery items on a shelf or in a freezer door display. Stimuli appeared on the computer screen similar to how the items are shelved in most grocery stores (e.g., cereals grouped on one aisle, canned soups on another, and frozen pizzas in the frozen foods section). The activity began with matching the target item to the only item appearing on the screen for a one-to-one correspondence. The instruction progressively became more difficult as more items appeared on the shelves to act as distracting stimuli. On the next level students had to match the target item from a choice of two items. The remaining levels for cereals included matching the target cereal to a field of four cereals, one shelf of 10 cereals, two shelves with 20 cereals, and three shelves with 27 cereals. The levels for soups were matching from a choice of one soup, two soups, three soups, one shelf of four soups, two shelves of eight soups, and three shelves of 12 soups. The levels for frozen pizza were matching from a choice of one pizza, two pizzas, one shelf of three pizzas, two shelves of six pizzas, and three shelves of nine pizzas. Meeting the criterion of three consecutive unprompted corrects or four out of five unprompted corrects allowed the participant to move to the next level.

A graduated response criterion was incorporated in each trial. The amount of time a participant had to respond varied according to the number of stimuli appearing on the screen. The computer displayed a model prompt was shown if the participant did not respond within the given amount of time or responded incorrectly. Following the model, the participant was given another chance to answer correctly with the same target item. For 1, 2, or 4 cereals on the screen, the response criterion was 5 s. For 10 items, the response criterion was 10 s. For 20 items, the response criterion was 20 s and for 27 items, the response criterion was 30 s. For soups, the response criterion was 5 s for 1, 2, and 3 soups, 10 s for 4 soups, 20 s for 8 soups, and 30 s for 12 soups. For frozen pizzas, the response criterion was 5 s for 1, 2, and 3 pizzas, 15 s for 6 pizzas, and 30s for 9 pizzas.

The program provided a model by explaining that the item the student needed to find was in the corner and that they should click the matching item on the shelves. It modeled one trial for the participant; then provided the task direction of "Click on the item that matches the item in your flipbook." If the participant made a correct selection, the item automatically moved into the shopping cart at the bottom left corner of the screen with a reinforcement prompt of "Good job," "Well done," "That's right," or "Great job." The next trial then began. If the participant made an incorrect selection, the program prompted, "That isn't the item that is in your flipbook. Let me show you" and then modeled how to scan left to right and top to bottom until the target item was found. A bright yellow box flashed around the correct match along with the auditory prompt, "This was the correct item. Try it again." If the participant was correct the second time, the item moved into the cart and the next trial began. If the participant made an incorrect selection again, the response was ignored and the next trial was presented. If the participant did not respond within the specified amount of time after the task direction, the computer modeled how to scan to find the same item. If correct, the procedures for a correct response were followed. If incorrect, the response was ignored and the next trial was presented. Only the participant's first response counted toward criterion (90% or above unprompted corrects for three consecutive sessions, but all responses were recorded to allow for error analysis. After the 40 trials, the computer saved the participant's name, the current level on which he or she was working, and all of the participant's responses in a database.

Reliability

The classroom teacher, paraprofessional, or a special

Table 3.
Summary Statistics

		Pre-Intervention Community Probes				Post Intervention Community Probes			
		Trained		Untrained		Trained		Untrained	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Abby	Cereal	45.83	19.09	25	25	77.08	14.91	52.08	16.71
	Soups	10.42	12.29	29.17	24.58	30.56	18.87	50	27.95
	Pizza	22.22	23.19	38.89	13.18	69.44	34.86	66.67	30.61
Kate	Cereal	52.08	16.61	33.33	20.14	86.11	9.77	69.44	20.83
	Soups	2.78	5.51	13.89	13.36	37.5	13.69	62.5	20.91
	Pizza	20.833	23.44	12.5	13.06	100	0	91.67	14.43
Sue	Cereal	13.89	9.77	5.56	11.02	59.72	15.02	41.67	17.68
	Soups	3.41	8.08	9.09	16.86	22.92	20.03	41.67	20.41
	Pizza	14.58	16.71	6.25	11.31	66.67	38.19	58.33	28.87
Brad	Cereal	93.75	8.43	75	10.66	98.61	4.17	97.22	8.33
	Soups	65.83	21.37	76.67	19.97	79.17	15.14	87.5	13.69
	Pizza	79.17	19.65	88.89	15.39	100	0	91.67	14.43

education graduate student collected observer and procedural reliability data during at least 26% of all sessions and at least one time per condition for each student. Interobserver reliability data was not collected during CBP and CAI sessions because the computer collected the data for those trials. The computer program was tested to make sure the data collected were reliable and consistent with the response made by the user. Interobserver reliability data were collected on accuracy of student response. The researcher trained all reliability collectors by explaining procedures and practicing the protocol in a role-play. Interobserver reliability was calculated using the point-by-point method of dividing the number of researcher and observer agreements by the number of agreements plus disagreements and multiplying by 100.

During GSP the independent observer determined if the researcher (a) positioned the student at the correct distance from the target item, (b) provide the task direction, (c) provide the correct amount of time to complete the task, (d) respond to the participant's response in the correct manner, and (e) allowed for an inter-trial interval of 5 seconds.

For CBP and CAI, the observer tracked whether the researcher (a) maneuvered through the program to the correct screen, and (b) provided verbal praise at the end for following directions. For probe sessions, the observer also tracked whether the researcher (a) told the participant on which icon to click to begin, and (b) told the participant on which icon to click to stop and pointed to it after 10 trials for each class of items. This differed slightly for intervention sessions where the observer tracked whether the researcher told the participant which icon to click on to stop and pointed to it after 40 trials. Procedural reliability for all conditions was calculated by dividing the number of observed researcher behaviors by the number of opportunities to emit the behavior and multiplying by 100 (Billingsley, White, & Munson, 1980). The percentage of agreement for each condition was computed.

Results

Reliability

During GSP sessions, interobserver agreement and procedural reliability were evaluated simultaneously. The mean interobserver agreement was 80% across all participants during GSP sessions with a range of (64-96). The mean interobserver agreement for accuracy of student response was 96% with a range of 95 to100. The mean procedural reliability across all participants and conditions was 100%.

Acquisition and Generalization

All students accurately located more items following intervention than they did during baseline conditions. Table 3 shows a synopsis, by item, of mean student performance. To summarize community probe performance, Abby correctly located to 27.57% of target stimuli before intervention and 61.1% of stimuli following treatment. Kate's improvement was larger averaging 19.67% in pre-intervention and 71.53% following intervention. Sue responded accurately on only 9.2% of occasions prior to intervention compared 46.52% of occasions following intervention. Brad, already responding correctly to 78.86% of stimuli during pre-intervention probes, improved and accurately located 92.7% of the items following intervention.

Figures 2 and 3 depict a time-series data of the students' performance across conditions. In the condition labeled GSP, closed diamonds represent the percentage of trained stimuli

Figure 2. Abbey and Kate

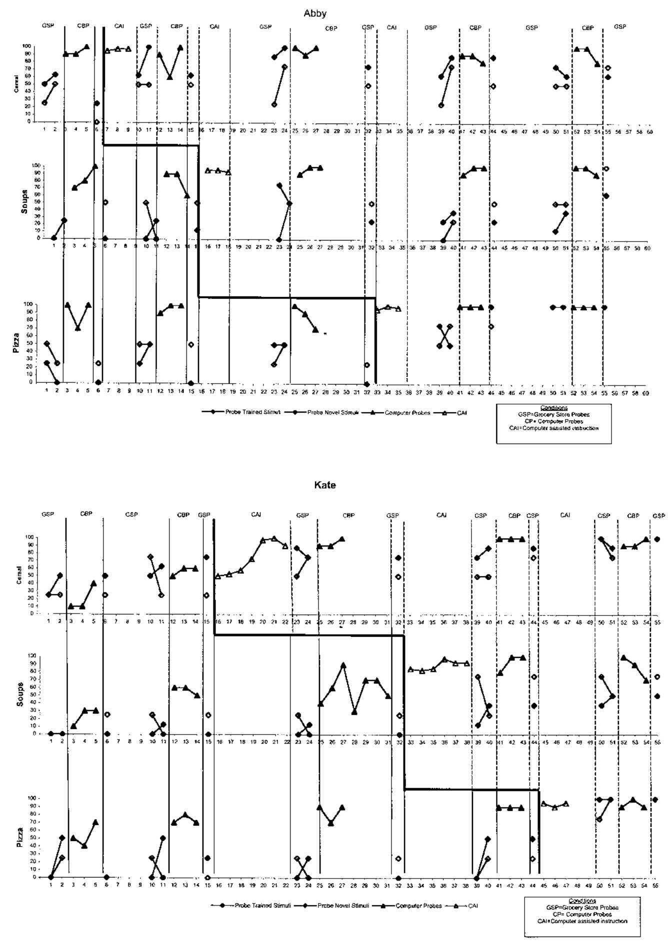
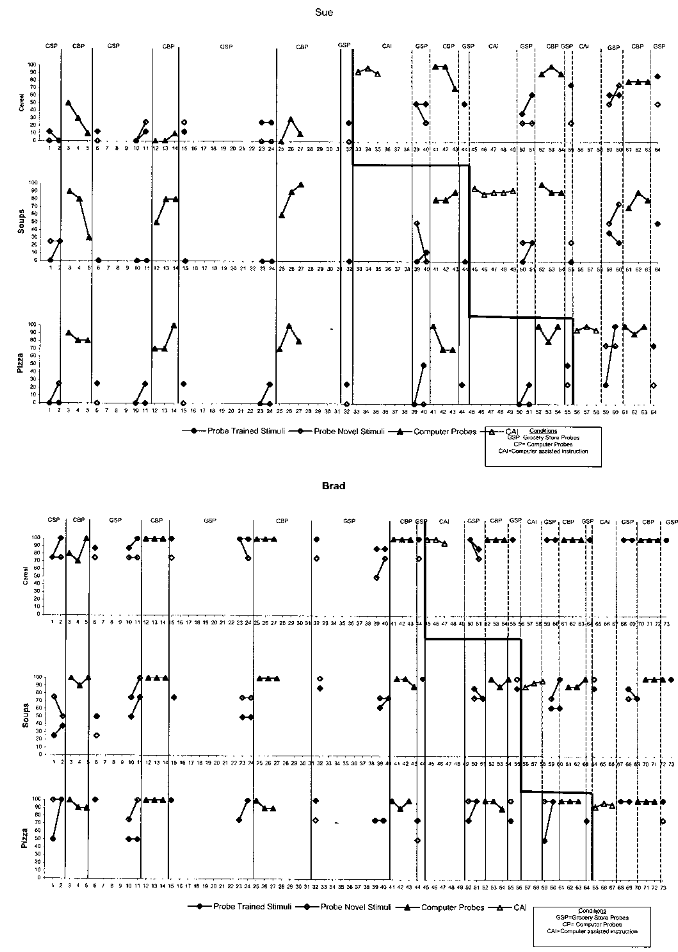


Figure 2. Sue and Brad



(i.e. stimuli appearing in the computer instruction) that the students accurately located in the community. The open diamonds represent accurate responding to untrained stimuli. In cases where only one diamond appears in a GSP condition, this is the result of the two data points overlapping therefore appearing as one diamond.

Abby's performance in baseline GSP was relatively low. During CBP she showed high levels of accuracy and she quickly acquired correct responding during CAI. Demonstrating generalization, the GSP data immediately following intervention was higher when compared to the last GSP prior to intervention. The results for locating soup were mixed with some improvement over baseline performance but then returned to near baseline levels until the 55th session where her performance rose to 100% correct for the trained stimuli. This corresponded with her performance with pizza where she made improvements after intervention but did not achieve 100% accuracy until the 55th session.

After acquiring item location via CAI on cereals, Sue's GSP data improved marginally over baseline levels for several sessions ultimately reaching a high of 87.5% correct for trained stimuli in session #64. Even with a low baseline level for soups, Sue's performance after intervention did not show large immediate increases. Her performance increased to the highest levels in the 60th session at 75% correct for novel stimuli. With pizza, Sue also showed variable low levels of accuracy but with a slight increase before intervention. Following intervention her GSP data climbed to highs of 75% and 100% for novel and trained stimuli respectively.

Kate demonstrated variable performance in baseline GSP for cereal and took seven sessions to meet criterion during CAI. Grocery store probe data directly following the last CAI session showed performance that overlapped with baseline performance for trained stimuli but was higher for untrained stimuli. Following introduction of intervention for locating soups, Kate's performance on cereals increased. Her initial data following CAI for soups showed increases for trained and untrained stimuli with one data point overlapping with baseline performance in each category. With pizzas Kate showed an immediate and abrupt change in level for locating the items above baseline performance.

Of the four participants, Brad exhibited the highest baseline performance on GSP probes. He consistently located 100% of the cereals targeted for training in baseline GSP probes. Following intervention he maintained the high levels for cereals in training and his accuracy for locating the untrained stimuli stabilized at 100%. Similarly, with soups and pizzas, Brad demonstrated the ability to locate 100% of the items in both the trained and untrained items prior to intervention with no noticeable changes following intervention.

Discussion

The purpose of this study was to evaluate the effectiveness of a CAI program to increase the percentage of correctly selected grocery store items and to see if a discrimination skill generalized to the natural setting for the four participants with moderate to severe disabilities. Specifically, the study evaluated the number of correctly selected items and generalization to the grocery store. The percentage of correct responses increased in the grocery store while anecdotal data revealed that the time to locate items decreased after the CAI. This later finding, while requiring more rigorous methodological inquiry, signals another possible utility for CAI.

This study added support to the literature base supporting the use of multimedia-based instruction to improve social skills (e.g. Alcantara, 1994; Wissick, 1992; Ayres & Langone, 2002). Comparison of pre-intervention to post intervention means clearly show improvements in performance. Whether or not one can attribute these improvements to the CAI is disputable. Traditionally in multiple probe designs, one looks for immediate changes in performance following introduction of an intervention (Tawney & Gast, 1984). While all of the students quickly acquired the skills on the computer, most scored well on computer baseline probes. In the case of Sue, performance on CBP for soup and pizza increased as soon as she began intervention for cereals, suggesting that she only needed more practice with the computer program. In the case of the four participants in this study, changes occurred in community performance but the changes were not always immediately after intervention. For Abby, Sue, and Kate, several additional probe sessions (on the computer as well as in the community) in addition to introduction of the intervention on the next set of stimulus set took place. This suggests that probing may have ultimately had a facilitative effect.

Limitations of the Study

One obstacle that makes the interpretation of these findings difficult is that Brad, Abby, and Sue all had some skill at locating items in the community prior to intervention. Absolute level changes became more difficult to judge. Future studies should focus more on customizing the software to meet the specific needs of the participants thus allowing more demonstrable effects.

In regard to the intervention, the instructional format of the program lacked some components of teaching. For example, when the computer gave the controlling prompt after an incorrect or no response, no verbal direction followed telling the student how to scan the shelves for an item. The computer simply told the student that the item he or she selected was incorrect. More explicit instruction might have enhanced generalization. For example, the participant could be told to scan left to right, side to side, and top to bottom, which could then be enhanced with a video vignette of a real shopper scanning shelves for a similar item.

Because of the constantly changing images on products (e.g., some cereal boxes display many different athletes in a single year), cereal photograph availability and sharpness of the photograph after minimizing the images, half of the cereals were a non-identity match. This programming challenge could lead to difficulty for students already challenged when having to make a conditional discrimination if they do not know what aspects of an item label are critical to making a match (e.g., boxes are always bright orange with blue letters). Alternatively one could view these natural variations as an advantage for generalization purposes.

Future Research

As suggested for future research by Mechling et al., (2003), this computer program included direct selection of the items on the screen to allow for active responding. Teaching the discrete task of making a correct discrimination was basis of this study. Future researchers could include more of a complete grocery shopping experience instead of focusing on an isolated skill. This could easily be made possible with the incorporation of videos that help to set the context for the targeted skill.

The results from this study provided an alternative way for teachers to teach students with disabilities how to perform skills that are used in the community without visiting the community environment. Students could work on the computer multiple times a day and independently unlike community-based instruction or classroom simulations. Software could extend the community experience allowing repeatable, recyclable teaching opportunities in the classroom.

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Internet-Based Multimedia Tests and Surveys for Individuals with Intellectual Disabilities

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Students and adults with intellectual disabilities face multiple obstacles when taking tests, assessments, evaluations, questionnaires, and surveys. Significant impairments in literacy can make common formats for soliciting objective and subjective feedback—such as written questions and answers—inaccessible to many people with intellectual disabilities. This brief report provides results of a pilot test of an Internet-based multimedia testing and assessment system employing audio, video, and picture supports to enable individuals with intellectual disabilities to more independently complete online tests and assessments. Twenty-two adolescents and adults participated in the study. Participants needed an average of 7.5 prompts to complete a traditional written test, while those same individuals required only 2.2 prompts to complete the online version of the test. These results suggest the feasibility of utilizing a self-directed, multimedia software approach for creating an independent and potentially integrated test-taking format for individuals with intellectual disabilities or literacy challenges.

Assessment has always been an integral component of the educational process, but the importance to students of performing effectively on district and statewide tests has increased the visibility of testing and assessment for students with and without disabilities. There are several factors that limit the reliability of common testing formats for students with intellectual disabilities, including limitations in literacy and problems with fine-motor and eye-hand coordination. Even when students with intellectual disabilities can read test or survey items, they may focus on an irrelevant aspect of the question. Finally, there are often difficulties with determining the best response format for students in this population. Individuals with intellectual disabilities are more likely to respond in an acquiescent manner, and there is concern that yes/no test formats may be unreliable due to this acquiescence bias. On the other hand, students have difficulty understanding gradations between options in a Likert-format scale (Sigelman, Budd, Spanhel, & Schoenrock, 1981; Wehmeyer, 1994).

For these reasons, educators working with students with intellectual disabilities tend to minimize or eliminate the use of standard testing or survey formats, choosing instead to employ a variety of assessment methods to determine student progress and knowledge or skills, including ecological inventories, task analytic assessment, curriculum –based assessment, portfolio assessment, and so forth (Browder, 2001; Macfarlane, 1998). There are, however, situations in which information derived from more traditional test, self-report questionnaires, or survey formats would be useful for educational purposes.

There is increased emphasis in special education practices on the importance of universal design for learning (UDL) and for universally-designed materials if students with disabilities are to access the general curriculum (Rose & Meyer, 2002), including students with more severe disabilities (Wehmeyer, Lance, & Bashinski, 2002). Issues of universal design and students with intellectual disabilities were discussed in the introductory article to this special issue (Wehmeyer, Smith, Palmer, & Davies, this issue) and JSET readers are well aware of the application of UDL principles through the JSET Universal Design for Learning columns. As such, we will simply note that the application of principles of UDL to assessment formats has the same potential to ensure access for students with cognitive impairments that the application of these principles to curricular presentation and content has. While it is likely the case that the educational assessment of students with intellectual disabilities will best be accomplished through multiple means, there is potential value to examining how typical testing or survey formats can be modified so as to be useful with this population.

The objective of this pilot study was to determine the technical merit, feasibility of use, and required functional features of an Internet-based multimedia software approach for creating independently accessible and self-directed tests and assessments for individuals with intellectual disabilities. The goals of this project follow:

1. To define the interface, functional and technical requirements for a prototype software system designed to enable individuals with intellectual disabilities to respond to test, assessment or other evaluation questions in an independent and self-paced manner.
2. To implement these requirements in a fully functioning, Internet-based software prototype.
3. To conduct a pilot study to measure the effectiveness of the prototype against existing tools and systems for administering assessments or tests in the areas of self-direction, independent use, accuracy of results and efficiency of process.

These objectives were accomplished by designing, building and field testing an Internet based software prototype, called QuestNet, utilizing support from both a public school transition program and local adult service provider agencies. The specific project task steps included (a) preliminary requirements development, (b) initial design and prototype development, and (c) evaluation of the QuestNet prototype.

Method

Participants

Study participants were 22 adolescents and adults with intellectual disabilities recruited from a public school 18-21 transition program and from an agency in the same community providing supports to adults with developmental disabilities. Thirteen participants were male and nine were female. The mean IQ score for study participants was 55.93, (SD = 8.38 , range = 45-69), and the average age was 28.3 (SD = 11.32 , range = 18-49). Key persons in each agency were initially contacted concerning interest in participating in the study, and then all students and adults served by the programs were invited to participate. The final sample consisted of those participants who returned informed consent. All participants received compensation for their participation.

System Design

The software authoring tools in *ASP.NET* were used to develop and integrate the software modules and databases for the prototype system. *FlashMX* was the core development tool used to encapsulate audio, video, and digital image media used to create the online multimedia test format. An opening screen was developed to allow researchers to easily initiate a session by clicking the link for the appropriate test (A or B), as described subsequently. Study participants were not required to use this screen.

After the researcher, an employee of AbleLink Technologies, chose the appropriate test form, the first question was presented to the participant. For all question types, questions and potential answers were automatically presented on screen in text format, along with an audio recording of the question and a prompt for making an appropriate response. For example, the first question in Test A was presented both in text and as an automated audio recording: "Are you satisfied with the staff that provide your services and supports? Please click in the box next to your answer." If the participant used a mouse, placing the cursor over a potential answer played a recorded message stating that answer option (e.g., "Yes", "No", "Sometimes").

If a touch screen interface was used, the same recorded audio answers played when the user tapped the box next to each answer. In other words, if the user tapped the box next to "Yes," the answer was read aloud by the computer to confirm the selection, and a red check mark was entered in the box. The check boxes were created as a toggle switch, in that if it was clicked or tapped once the check would appear; a second consecutive click would remove the check from the box. Users could change answers at any time by selecting the box next to a different answer.

Upon selecting an answer, a large button with a blue arrow on it was displayed along the right vertical edge of the screen. This button was used to move to the next question. As an example of error minimization techniques used in the prototype software, the button to move to the next question was only available on screen when an answer had been selected. If the user selected an answer and then de-selected it, the arrow button was removed from the screen. This error minimization feature prevented participants from accidentally moving to the next question without providing an answer for the previous one. The final element of the user interface involved a button with an image of an ear that was available in the upper right corner of each screen. Users could select this ear button at any time to replay a question.

After the user successfully answered Question 1 and clicked the blue arrow button, Question 2 was cued and the sequence repeated. The audio for Question 2 on Test Form A stated "Do you get to go out in the community for activities as often as you would like? Be sure to check the box next to your answer." After responding, Question 3 was cued, and so on until the final question. After completing the last question, a closing screen was displayed with an audio message stating "The survey is now complete. Thank you very much for your time."

Test Forms

The project team selected questions based on items from existing test instruments in use by the participating school or

Table 1
Comparison of Two Tests Developed for Pilot Study

Test A		Test B	
Question	Answer Set	Question	Answer Set
1. Are you satisfied with the staff that provide your services and supports?	Yes/No/Sometimes	1. Do you feel that your teachers or staff listen to you when you have a problem?	Yes/No/ Not Sure
2. Do you get to go out in the community for activities as often as you would like?	Yes/No/Sometimes	2. If you are not happy about something, do you know who to talk to about it?	Yes/No/ Not Sure
3. Check the box for the picture below that shows someone slicing.	Chose between two hand drawings	3. Check the box for the picture below that shows someone grating lemons.	Chose between two hand drawings
4. Check the box for the picture below that shows someone sifting.	Chose between two hand drawings	4. Check the box for the picture below that shows someone basting a turkey.	Chose between two hand drawings
5. Check the box for the picture of the job that shows someone operating a machine:	Chose between two digital pictures	5. Check the box for the picture that shows someone doing a job making beds:	Chose between two digital pictures
6. Check the box for the picture of the job that you think is noisier.	Chose between two digital pictures	6. Check the box for the picture for the job you think is noisier.	Chose between two digital pictures
7. Smoke from a fire is thinner near the ceiling.	True/False	7. For minor cuts and scrapes, wash the wound with soap and water.	True/False
8. Sharp knives can safely be washed with the silverware.	True/False	8. It is okay to buy a bulging food can if it is on sale.	True/False

agency. Items were selected and generated to ensure that participants responded to several question and answer formats across several multimedia formats. Two test forms, labeled A and B, were developed for use in the study. Each form included eight questions identical in format and sequence but differing slightly in content. Both tests included (a) two questions using a "yes/no/sometimes" response, (b) two multiple choice questions using hand drawn pictures, (c) two multiple choice questions using digital pictures, and (d) two true/false questions.

As described in the session procedure section, participants completed an online version (e.g., *QuestNet*) of either Form A or B, and the written version of the other form. The minor differences in content were considered inconsequential to the study, as there was no attempt to determine the accuracy of answers. Table 1 illustrates the differences between test forms.

Research Design

A two-group, within-subjects design was utilized for the pilot study. Participants underwent testing using both the traditional written test and *QuestNet*. Both the order of presentation and the test form used in each condition were randomized to control for ordering effects. Each participant received training prior to engaging in each testing condition. A sample test was developed that included one of each type of questions listed above. This sample test was implemented in both the written format and in the software prototype. Participants were trained on each version of the sample test (written and online) until they mastered the ability to provide an answer to each question type, regardless of whether the answer was right or wrong. Three individuals were unable to meet this criteria for the sample test, and therefore received their participation fee and were excused from the study. No data from these individuals were included in the results.

Test Procedures

Each test session involved the following sequence of activities.

1. The order in which test format (written or online) would be presented was randomly determined.
2. The test form (A or B) that would be taken in the written or online format was randomly determined.
3. Training on the written version of the sample test was provided.
4. If participant showed mastery of test completion using sample test, written version of form A or B was completed in written format.
5. Training on software version of sample test was provided.
6. If participant showed mastery of test completion using sample test, online version of form A or B was completed.

Data Collection

A form was developed along with detailed instructions for collecting data on participant performance during the pilot study. Researchers observed pilot study sessions and documented prompts and errors in accordance with the detailed written procedures for administering the assessment. Of the 22 test sessions conducted, 16 included more than one data coder. Coders were trained using a data collection script that was developed for the study. The training script was developed initially by anticipating potential actions of participants, and was refined by observing a series of practice trials of the procedure using both project team members and local volunteers with intellectual disabilities. Coders then used the training script to record data on a series of practice trials. For example, if a participant needed direction on where to click next in the online system, or if he or she asked that a question or word be read to them, a prompt was recorded. However, if a participant asked a question unrelated to independent test-taking such as "Should I answer yes?," no prompt was recorded and the participant was told to simply provide the best answer they could.

Data Analysis

Data from the pilot study was analyzed with *SPSS PC+ for Windows* to determine if the results were statistically relevant. The study utilized a standard within-subjects paired samples research design to compare the degree of independence and frequency of error between the two conditions. The analysis conducted was a t-test for paired samples. Significance was tested at the p = .05 level. Inter-rater reliability was determined by dividing the number of possible agreements by the number of actual agreements, multiplied by 100.

Results

Inter-rater reliability for observations of prompts was .95, while for observations of errors it was .97. Table 2 provides a summary of results of comparisons between written and online versions of the tests. There were significant differences (p = .001) for the number of prompts required to complete the test as a function of the test format. Using the *QuestNet* prototype, participants required an average of 2.16 (*SD* = 2.72) prompts to complete the test as compared to an average of 7.48 (*SD* = 4.04) instances of assistance required to complete the traditional testing format. There were no significant differences in the mean number of errors made in completing the test.

Discussion

The results of this pilot study provided preliminary evidence that youth and adults with intellectual disabilities could independently complete a test using a self-directed multimedia software approach more reliably then when using a traditional written format. Sample size and the pilot nature of the study limited the generalizability of the findings, certainly, but there were several benefits to online testing tools that emerged as a result of the study. Perhaps the most evident reason was the capacity of the *QuestNet* to provide literacy supports enabling participants to have the question

Table 2.
QuestNet Pilot Study Results (n = 22)

Condition	QuestNet	Traditional	One-tailed Significance
Average Incidence of Assistance/Prompts Required to Complete Test	Mean = 2.16 SD = 2.72	Mean = 7.48 SD = 4.04	$p < .001$
Average Incidence of Errors Made in Completing test	Mean = .32 SD = .699	Mean = .46 SD = .800	$p = .195$
Average Percent Correct	64%	64%	—

read to them. Error rates on both testing approaches were surprisingly low. Although more total errors were made when engaging in traditional test taking than when taking the test using the online multimedia version, the difference was not statistically significant. However, all but three of the errors made during the *QuestNet* sessions were due to the test subject forgetting to first run the video clips on questions using that format, an issue that can be corrected through a redesign of the *QuestNet* interface.

Three basic question and answer formats were implemented in the multimedia online prototype. The first format, questions with variations of the yes/no responses, appeared to be the most familiar and easiest to respond to by participants. There was, however, the potential, as noted previously, of a tendency toward acquiescent responses, and it is important to conduct more research to examine whether multimedia formats can reduce such acquiescent responding. The next most accessible response format used in the study was multiple choice, single response (that is, only one answer was chosen). Within the four multiple choice questions, two involved choosing between responses represented by line drawings, and two questions had answer sets represented by digital images. Although the study did not specifically analyze differences between line-drawn images and digital photographs, observation notes indicated that some subjects had greater difficulty with the more abstract line drawings than with the digital pictures. This was also a candidate for further evaluation. The third question and answer format evaluated in this project was true/false. Although this is a common format for testing, it appeared to be the most difficult for participants to comprehend. Participants frequently exhibited long hesitations at answering these questions, or made statements such as "I don't get it" or "I need help with this one."

For most adolescents or adults who participated in the study, using the specialized online testing system provided clear advantages. Participants—even those who demonstrated functional literacy skills—uniformly preferred the online system to paper and pencil testing. Participants made comments related to enjoying the control and self-pacing provided by the system as well as the multimedia features, including: "It's easier." "I like it better because I'm good at it." "I like the computer because its easier than paper." "I wish I had one of these at home." and "I never did a test by myself before!"

In general, users seemed to appreciate the opportunity to independently take a test with minimal assistance of another person. The empowerment of more independent test taking, along with the self-esteem of successful computer use, appeared to be primary factors in their preference for *QuestNet.* Additional factors may include the relative novelty of viewing video clips on a computer, use of a touch screen interface (this was made optionally available to test subjects), and the sense of being in control of their environment.

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The authors would like to thank those individuals who volunteered to participate in the QuestNet pilot study and other activities conducted in this project. Additionally, our appreciation goes out to the staff at Cheyenne Village, Inc., Martin Luther Homes, and Colorado Springs School District 11 who provided opinions, feedback, and otherwise facilitated various tasks in the project.

Emerging Technologies and Cognitive Disability

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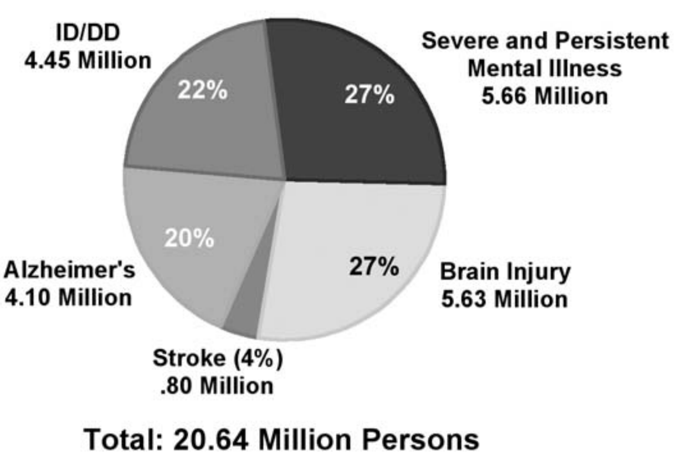
Despite the potential of emerging technologies to assist persons with cognitive disabilities, significant practical impediments remain to be overcome in commercialization, consumer abandonment, and in the design and development of useful products.

Barriers also exist in terms of the financial and organizational feasibility of specific envisioned products, and their limited potential to reach the consumer market. Innovative engineering approaches, effective needs analysis, user-centered design, and rapid evolutionary development are essential to ensure that technically feasible products meet the real needs of persons with cognitive disabilities.

Efforts must be made by advocates, designers and manufacturers to promote better integration of future software and hardware systems so that forthcoming iterations of personal support technologies and assisted care systems technologies do not quickly become obsolete. They will need to operate seamlessly across multiple real-world environments in the home, school, community, and workplace.

Cognitive disability entails a substantial limitation in one's capacity to think, including conceptualizing, planning, and sequencing thoughts and actions, remembering, interpreting subtle social cues, and understanding numbers and symbols. Cognitive disabilities include intellectual disabilities and can also stem from brain injury, Alzheimer's Disease and other dementias, severe and persistent mental illness, and, in some cases, stroke (see Figure 1). More than 20 million persons in the United States have a cognitive disability -- and the number of individuals with cognitive disabilities such as Alzheimer's disease is expected to increase rapidly as the nation's population ages (Braddock, 2001).

Figure 1. Cognitive Disability in the United States



Utilization of Technology

Many persons with cognitive disabilities utilize assistive technologies to enhance functioning in activities of daily living, control of the environment, positioning and seating, vision, hearing, recreation, mobility, reading, learning and studying, math, motor aspects of writing, composition of written material, communication, and computer access. Technologies used range from low-tech devices, such as pictorial communication boards or adapted eating utensils, to high-tech devices including adapted software and voice output devices with speech synthesis (Technology and Media Division, 2003).

An assistive technology device is defined in the Technology Related Assistance for Individuals with Disabilities Act of 1988 (Pub. L. 100-407) and the Assistive

Technology Act of 1998 (Pub. L. 105-394), as "any item, piece of equipment, or product system, whether acquired commercially, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Title 29, Chapter 31, § 3002(a)(3)). The term assistive technology service is defined in the Technology Related Assistance for Individuals with Disabilities Act of 1988 (Pub. L. 100-407) and the Assistive Technology Act of 1998 (Pub. L. 105-394), as "any service that directly assists an individual with a disability in the selection, acquisition, or use, of an assistive technology device" (Title 29, Chapter 31, § 3002(a)(4)).

To date, much of the research on assistive technologies for persons with cognitive disabilities has focused on the benefits of augmentative and alternative communication (AAC) aids. "In the broadest sense, the goal of AAC interventions is to assist individuals with severe communication disorders to become communicatively competent today in order to meet their current communication needs and to prepare them to be communicatively competent tomorrow in order to meet their future communication needs" (Mirenda, 2001, p. 142). AAC research has helped disprove the previously widely held belief that persons with significant levels of cognitive disabilities could not benefit enough from communication devices to justify the cost (Light, Roberts, Dimarco, & Greiner, 1998; McNaughton, Light, & Arnold, 2002; Romski & Sevcik, 1997; Turner, 1986, cited in Romski & Sevcik, 2000). Speech recognition and output technology, in particular, has been shown to greatly enhance the participation of individuals with disabilities in educational and other daily activities (Cavalier & Brown, 1998; Lancioni, O'Reilly, & Basili, 2001; Mechling, Gast, & Langone, 2002; Romski, Sevcik, & Adamson, 1999).

Confluence of Advances in Technology

Until recently, when the term technology was used in conjunction with cognitive disability, it most likely referred to an assistive technology device, such as one for augmentative and alternative communication or a switch to control the environment. State-of-the-art technological advances in computer science, engineering, communications, rehabilitative science, and microelectronics have rarely been adapted for people with cognitive disabilities. However, the number of people with cognitive disabilities is expected to increase rapidly in future years, and as a result there is increased interest in developing and marketing new technologies for people with cognitive disabilities. Cognitive technologies have the potential to help persons with cognitive disabilities, and those with age-related cognitive decline, to achieve greater independence, productivity, and quality of life (Bowles, 2003; Eisenberg, 2002; Hammel, 2000; Hammel, Lai, & Heller, 2002; Merritt 2003).

Product engineering is evolving from stand-alone devices and applications to distributed, connected, integrated, and multi-technology systems (Kurzweil, 1990, 1999, 2002). Electronic products are becoming smart and software systems are becoming adaptive and personalized. The movement toward smaller, easier to use, micro-technologies, with larger-scale integration, increased performance, and reduced price not only benefits the general population, but also has the potential to benefit those with cognitive disabilities. Three arenas of technology advancement in cognitive disability are described below: personal support technologies, assisted care systems technologies, and virtual technologies.

Personal Support Technologies

Personal Digital Assistants

Personal support technologies (PST), such as personal digital assistants (PDAs), have the ability to greatly enhance the independence, productivity, and quality of life of persons with cognitive disabilities (Bergman, 2002; Grealy, Johnson, & Rushton, 1999; Hart, Hawkey, & Whyte, 2002). For example, parents or caregivers can pre-program a PDA or desktop software with educational, vocational, or daily living tasks to prompt individuals with cognitive disabilities to perform a wide variety of well-defined vocational and independent living tasks (Davies, Stock, & Wehmeyer, 2002a). Specialized PDA software is currently available for enabling individuals with developmental and other cognitive disabilities to manage personal schedules with much greater independence (Davies, Stock, & Wehmeyer, 2002b), for helping direct individuals during their work tasks (Davies, Stock, & Wehmeyer, 2002a; Furniss et al., 2001; Furniss & Ward, 1999), and for assisting with activities of daily living (Lancioni, O'Reilly, Seedhouse, Furniss, & Cunha, 2000; Lancioni, O'Reilly, Van den Hof, Seedhouse, & Rocha, 1999). PDAs can also interface with wireless communication protocols to track and monitor an individual's daily activities, and provide prompts to the individual as needed to complete educational or work tasks (Furniss et al., 2001; Kautz et al., 2001; O'Hara, Seagriff-Curtin, Davies, & Stock, 2002). PDA technology has also benefitted individuals with traumatic brain injury (Cole, 1999) and communication disorders (McDonough, 2002).

Computer Assisted Learning and Communication

Other personal support technologies include specialized computer training programs (Davies, Stock, Wehmeyer, 2003, 2004), voice interfaces (Barker, 2002), picture-based email programs, and adapted Web browsers such as WebTrek (Davies, Stock, Wehmeyer, 2001). Wearable computers can also assist students with cognitive disabilities. For example, a wearable data glove has been developed by an engineering student at the University of Colorado that translates

American Sign Language and transmits this information wirelessly to an electronic display (Patterson, 2002).

Access to personal support technologies can benefit individuals in the classroom to remain on task, remind them of pending assignments, and provide access to information on the computer or the Internet. The effectiveness of computer-based learning techniques for students with cognitive disabilities has been well documented (Alcade, Navarro, Marchena, & Ruiz, 1998; Bernard-Opitz, Sriram, & Nakhoda-Sapuan, 2001; Blischak & Schlosser, 2003; Scruggs & Mastropieri, 1997). [See Wehmeyer et al. this issue for a comprehensive review of the research conducted on technology use by students with intellectual disabilities].

Despite the benefits to be gained, however, studies indicate access to computers and the Internet for persons with cognitive disabilities in the classroom and at home lags behind access for persons without disabilities (Abbott & Cribb, 2001; Aspinall & Hegarty, 2001; Johnson & Hegarty, 2003; Kaye, 2000). Almost 60% of persons with disabilities have never used a computer, compared to less than 25% of persons without disabilities (Abramson, 2000). Less than 10% of persons with disabilities have access to the Internet, compared to 38% of persons without disabilities. A discrepancy also exists in computer ownership. Less than 24% of people with disabilities own a computer, compared to over 50% of persons without disabilities (Kaye, 2000). The rates of access for persons with cognitive disabilities are undoubtedly even lower than the above-cited statistics, which apply generally to persons with disabilities. Some researchers, however, posit that with advances in computer power and declining costs, increasing numbers of students with disabilities will have appropriate access to necessary technologies (Hasselbring, 2001). However, as noted by Tinker (2001), education tends to follow well behind other sectors of society in terms of technology utilization. In addition, this problem can be exacerbated in special education because it comprises a small market relative to general education.

Universal Design

Universal design principles are necessary to ensure that persons with cognitive disabilities are able to utilize common technologies available to the general public. Universal design intends that products -- especially software and computers -- provide an interface that is suitable for all potential users, including persons with disabilities. Web standards, such as User Agent Accessibility Guidelines (Festa, 2002), federal regulations - such as Section 508, and public/private initiatives, such as the World Wide Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C), promote access to software and the internet for people with disabilities. But how does one define accessibility? Elbert Johns, Director of TheArcLink, (as cited in Rizzolo, Bell, Braddock, Hewitt, & Brown, in press) has suggested the importance of clearly defining the principal components of accessibility as this term pertains to people with intellectual and developmental disabilities and their use of information technology. Specifically, he notes that for information to be accessible to a person with an intellectual disability, it must (a) decrease the dependence on rote memory as a tool for recalling information, (b) use as many complementary formats as possible [visual, audio, multi-graphic], (c) reduce the need for the recipient to utilize complex organizational skills for comprehension, and (d) be presented in a vocabulary or reading level that approximates the level of the recipient. More intuitive, user-centered, computing interfaces are necessary to increase accessibility and empower persons with cognitive disabilities to use common technologies such as the Internet and personal computers.

Assisted Care Systems Technology

Another area of emerging technology for persons with cognitive disabilities is assisted care systems technology. These technologies are designed to assist caregivers of individuals with cognitive disabilities, and can range from simple monitoring devices to complex assisted care systems (ACS) integrated into the infrastructure of a building. These emerging technologies can assist in promoting the independence and health of persons with disabilities — including persons with cognitive disabilities — while maintaining safety.

Smart Houses

One example of an assisted care system is the *smart* home. Smart homes and rooms (Pentland, 1996) combine tracking technology and environmental control to provide robust prompting, including environmental cues such as adjusted lights (Lancioni & Oliva, 1999), and simplified operation of household systems. Many companies, such as Microsoft, Honeywell, and Intel, and universities such as MIT and Georgia Tech, are researching smart home technology as beneficial examples of ubiquitous computing. One company is already developing and using smart home technology to help care for residents with early-stage Alzheimer's disease in assisted living facilities (Elite Care, 2001). Research at the University of Colorado at Boulder is also underway to apply similar smart supports technology to community and family-based settings for persons with developmental disabilities (Taylor, 2003).

Residential assisted care systems integrate indoor/outdoor tracking systems, bio-sensors, building automation, databases, computer networks, and eventually, learning algorithms. Assisted care systems could provide numerous benefits for persons with cognitive disabilities, their families, and caregivers. For example, tracking systems can provide feedback to direct support employees and relatives on daily living activities (Elite Care, 2002). Pattern-recognition and learning software can be used to alert direct support employees of impending risks or adverse events, including social isolation and abnormal behavior (Elite Care, 2002). Building automation can simplify or control operation of household systems, including disabling an appliance or unlocking a door when a resident reaches their room. Though the research to date has focused on how these systems can promote independence in residential settings, much of the technology has the potential to be applied to other environments including the work site and the classroom.

Smart Transportation/Tracking Technology

Another example of smart technology is the smart transportation system. This system can assist persons with cognitive disabilities with mass transportation by utilizing wireless technologies and personal digital assistance devices such as the global positioning system (GPS) (Fischer & Sullivan, 2002). Travelers can be alerted when their GPS-equipped bus is arriving, and caregivers can be notified if the traveler has boarded the wrong bus. Problems with transportation have been cited as one of the most pressing barriers to the full integration of persons with disabilities into community life (New Freedom Initiative, 2001). The availability of reliable and safe transportation options can be an essential precursor to the successful transition from school to work.

Tracking technology is also a potentially useful ACS strategy to address wandering. Over 50% of respondents in a survey by the National Down Syndrome Society (2001) identified wandering as a significant problem. Many of the respondents indicated that wandering behavior occurred at night. Companies have developed both personal devices and home-based systems to address this need (Digital Angel, 2002). Utilizing GPS or local tracking data, monitoring devices can also alert caregivers in the event of a fall or unusual activity, or help locate persons who wander.

Assisted care systems can also be used to monitor the health of persons with cognitive disabilities. For example, ACS can integrate data from devices that passively monitor biomedical signs (e.g., smart bed sheets or more conventional vital signs monitors). With novel algorithms to estimate health states (Pavel, 2002), ACS can provide an unobtrusive, continuous picture of an individual's health. Research is also being conducted involving more focused, personal health advisory systems for the home (Fauchet, 2002). In the classroom, these systems could assist educational staff to monitor the health status of individuals with complex disabilities in an unobtrusive way during school hours.

Personal Robots

Robots have also emerged as a novel way to supplement the role of caregivers (Dario, Guglielmelli, Laschi, & Teti, 1999; Excell, 2004). Researchers at Carnegie Mellon and the University of Pittsburgh have developed a nurse robot (Nursebot) to assist elders with activities of daily living including prompts to perform certain tasks and medication administration (Rotstein, 2004; Stresing, 2003). The role of robots in the provision of care to the elderly and persons with cognitive disabilities will increase as the general population ages, the need for long-term care increases, and the pool of potential caregivers declines. Analysis of data from the National Long Term Care Survey showed that utilization of assistive technologies was associated with fewer hours of personal assistance (Hoenig, Taylor, & Sloan, 2003). Future research should investigate the role these technological assistants can play in the school environment.

Virtual Technologies

A third emerging arena of technologies for persons with cognitive disabilities is virtual technologies. Virtual technologies attempt to create an experience that simulates an actual experience, and have the potential to promote the participation of persons with disabilities in educational and community activities. Virtual environments (VEs) range from desktop VEs operating on a personal computer to full-immersion, three-dimensional situations.

Studies have documented the benefits of providing instruction to students with cognitive disabilities using virtual technologies and computer-based simulations (Akhutina et al., 2003; Lannen, Brown, & Powell, 2002; Cromby, Standen, & Brown, 1996). For example, researchers at the University of Colorado have created "full-bodied three-dimensional animated characters" capable of engaging in "natural face-to-face conversational interaction with users"(Ma, Yan, & Cole, 2004, p. 1) . The animated character software program assists children with speech and reading difficulties to interact with animated characters to improve speech and language skills, and is currently available in English, Spanish, and other languages (Ma et al., 2004).

The use of virtual reality for educating persons with cognitive disabilities can overcome barriers of real-world training situations such as cost, safety and accessibility (Cromby et al., 1996). Researchers have utilized virtual technologies to provide instruction in community-based activities such as shopping, social interactions, and safety (Brown & Standen, 1999; Langone, Clees, Rieber, & Matzko, 2003). Use of virtual technologies in the classroom can be extremely motivating to students, can make abstract learning concepts more concrete, allow students to progress through an experience at their own pace, and encourage active participation rather than passive observation (Pantelidis, 1995). Furthermore, skills learned in virtual environments have been shown to successfully transfer to real world situations (Standen, Brown, & Cromby, 2001; Standen, Cromby, & Brown, 1997). Virtual environments have also been used to mentor adults with cognitive disabilities and the elderly (Brown & Standen, 1999).

Virtual technologies are also being used to promote the health and well being of individuals with disabilities. Researchers at the University of Colorado and the University of Illinois at Chicago are developing engaging and motivating exercise opportunities for persons with disabilities in their own homes through virtual exercise environments. This study investigated whether virtual environments could increase distributed exercise participation by addressing frequently reported transportation barriers (Bennett, Bodine, Mulligan, and Lightner, 2002). This project has the potential to assist individuals with cognitive disabilities living in dispersed living environments to achieve improved health outcomes (Rimmer, Braddock, & Pitetti, 1996). Future research and development in this area should investigate the feasibility of incorporating this technology into the school system to provide virtual exercise opportunities to persons with disabilities that adapt to the abilities of each individual. Virtual technology could track exercise goals for each student and allow opportunities for students to participate in virtual competitions with others with similar competencies.

Conclusion

Due to continuing advances in microprocessor speed and processing capacity, computing power is progressing at an exponential rate. It literally doubles every 12-18 months (Kurzweil, 1999). The rapid rate of progress in computing power suggests that personal support, assisted care, and virtual technologies will progress rapidly over the next decade, becoming substantially more personalized. There are also positive signs that the assistive technology industry is growing. According to a U.S. Department of Commerce survey (2003), 359 companies manufacturing assistive technologies reported sales of $2.87 billion in 1999, up 21.8% from 1997 sales. Market projections suggest that emerging neuroscience technologies, like brain-machine interfaces permitting brain control of robot arms or computers, will be a $3.6 billion industry by 2008 (Cavuoto, 2004). Advances in cognitive neuroprostheses (Horch, & Dhillon, 2004), stem cell transplantation (http://stemcells.nih.gov/index.asp), and therapeutic cloning in South Korea (Hwang et al., 2004), hold exceptional promise to benefit persons with cognitive disabilities, and with time, may significantly improve function in disorders such as Alzheimer's, Down syndrome, and Parkinson's disease.

Despite the potential of emerging technologies to assist persons with cognitive disabilities, there are significant practical impediments to be overcome in commercialization, consumer abandonment, and in the design and development of useful products. For example, existing barriers to widespread commercialization of emerging technologies include regulatory burdens imposed by the FDA and the economically disadvantaged status of many persons with cognitive disabilities — combined with limited private insurance and Medicaid/Medicare coverage and payment policies (US Department of Commerce, 2003).

Barriers also exist in terms of the financial and organizational feasibility of specific envisioned products, and their limited potential to reach the consumer market. Innovative engineering approaches, effective needs analysis, user-centered design, and rapid evolutionary development are essential to ensure that technically feasible products meet the real needs of persons with cognitive disabilities. The obsolescence of most technological devices after only a few years presents a significant barrier to persons with cognitive disabilities. Efforts must be made by advocates, designers and manufacturers to promote better integration of future software and hardware systems so that forthcoming iterations of personal support technologies and assisted care systems technologies do not quickly become obsolete. They will need to operate seamlessly across multiple real-world environments in the home, school, community, and workplace.

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2003 in Review: A Synthesis of the Special Education Technology Literature

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The professional literature continues to be an essential resource for scholars and practioners for filtering and highlighting new advances in research and practice. However, the ongoing challenges associated with too much information, inadequate tools for managing information overload, and too little time for professional development demand that new approaches to literature analysis and synthesis be explored. The purpose of this study was to examine recent additions to the extant knowledge base in special education technology using a methodology known as the comprehensive one-year research synthesis. Two questions guided the inquiry: How widely scattered is the literature on special education technology? and What have we learned lately? The table of contents from each issue of 31 journals in special education technology (n=5), special education (n=17), and educational technology (n=9) published in 2003 were studied. The procedures yielded a corpus of 814 articles of which 224 articles (28%) were judged relevant for this review as contributing to the emerging knowledge base on special education technology research and practice. Analysis of the literature scatter revealed relevant literature could be found in 30 journals but that a core set of 11 journals contributed 70% of the relevant articles. Content analysis of the relevant articles revealed a number of dominant themes in the literature during 2003: assistive technology, implementation issues, instructional design, instructional strategies, outcomes of technology, professional development, reading and technology, and technology integration. The limitations of the comprehensive one-year research synthesis methodology are discussed along with the new importance this tool may have in filling the void created by the recent restructuring of the ERIC system.

This review marks the fifth consecutive year in which I have used the comprehensive one-year research synthesis methodology to analyze the special education technology literature (Edyburn 2003, 2002, 2001, 2000). This work has been motivated by a desire to address the challenges associated with too much information (Swanson, 1998; Wurman, 1989), inadequate tools for managing information overload (Bush, 1945), and too little time to synthesize new knowledge into existing practices or engage in substantive change (Swanson, 1998; Willinsky, 1999; Wurman, 1989).

This past year, a new problem has emerged as a result of the restructuring of the ERIC system (http://www.eric.ed.gov). Established in the 1960s as the first large scale database for educators, the ERIC system has developed into the core resource for scholars and parishioners interested in accessing the professional knowledge base. While ERIC had its flaws, most notably the historical reliance on microfiche and the omission of key assistive technology journals, it is widely recognized as an essential tool for students, researchers, and educational leaders and served as the model for other professional databases such as MEDLINE. However, as of December 19, 2003, the ERIC system would be restructured. Essentially this meant that new documents would not be added to the system while a new contractor was identified. In essence, ERIC has been unplugged. When the new contractor takes over in 2005, it will be responsible for indexing only 1,000 journals, rather than the 4,400 journals indexed by ERIC.

The Traditional Tools of Scholarship

The recent restructuring of the ERIC system will significantly impact the work of scholars and practitioners interested in special education technology (SET). While the SET literature was only partially covered in the ERIC system, there are few assurances that the new system will adequately index the SET literature. As a result, the SET profession must raise some serious questions about the tools it needs to manage, access, and utilize the extant knowledge base.

One distinguishing characteristic of a scholar is the intimate knowledge and understanding of the published literature in one's discipline. This knowledge has been traditionally acquired through reading and studying professional journals. In support of scholarship in special education, various facets of professional journals have been studied to gain insight about publishing opportunities (Joyce & Joyce, 1990), characteristics of the literature (Black, 1974; Summers, 1986; Torgeson & Dice, 1980; Vockell & Asher, 1972), rankings of professional journals (Garrett & McLoughlin, 1995, Swanson & Alford, 1987), quality of published works (Garrett & McLoughlin, 1995), and the impact of published works as represented through citation analysis (Swanson & Alford, 1987; Vockel & Jacobson, 1983). Surprisingly, while some attention has been devoted to the scholarly use of the Web (Henry, 2002; Nachmias, & Gilad, 2002; Spinellis, 2003), generally little is known about how scholars and practitioners rely on the Web as a source of information for current awareness and professional decision-making.

Cooper and Hedges (1994) have noted that one tool, the literature review, is especially prized by scholars and practitioners because it serves a strategic function in managing information overload and facilitating access to the extant knowledge base. Naturally, this strategy has been utilized within the field of special education technology and has resulted in a number of useful works: comprehensive reviews of the literature (Edyburn 2003, 2002, 2001, 2000, 1995; Jeffs, Morrison, Messenheimer, Rizza, & Banister, 2003; Okolo, Bahr, & Rieth, 1993; Woodward & Rieth, 1997), and a comprehensive bibliographic index (Haus & Rieth, 1989).

While the value of integrative literature reviews is unquestioned, the fundamental approach is based on an in-depth review of a specific topic across time. Indeed, a taxonomy of approaches to research synthesis reflect this principle (Cooper & Hedges, 1994, p. 4). However, given the relative youth of the field of special education technology, methods that involve multi-year historical analysis fail to serve the information needs of a profession during the formative period when the literature base is being built.

Reflecting on the lack of tools for accessing the special education technology knowledge base, I wondered why research synthesis methodology could not be utilized in a different way. That is, why not conduct a synthesis of the literature across a one-year time period? The results of a comprehensive one-year review and synthesis would yield a response to the question, "What have we learned lately?" and provide researchers, scholars, and educational leaders with a new tool for accessing the emerging knowledge base. Such an approach appears to meet the basic definition of a literature review constructed by Cooper and Hedges (1994, p. 4):

> Common to all definitions of literature reviews is the notion that they are "not based primarily on new facts and findings, but on publications containing such primary information, whereby the latter is digested, sifted, classified, simplified, and synthesized" (Manten, 1973, p. 75).

Thus, the major attribute of the comprehensive one-year research synthesis approach is that it simultaneously addresses the problem of information overload and provides a new tool for accessing the extant knowledge base.

Research Questions

The purpose of this study was to investigate two research questions regarding the extant knowledge base: How widely scattered is the literature on special education technology? and What have we learned lately?

Literature Scatter

As a result of the proliferation of professional publications, questions have been raised concerning how widely one must read in order to maintain command of the key developments in a discipline. The field of library and information science refer to this issue as the problem of "literature scatter"(Lancaster, 1988). Bibliometric studies of the literature in a discipline provide evidence regarding the concentration or scatter of relevant information. A study examining the scatter of literature on learning disabilities found that while articles about learning disabilities could be found in 248 journals, a core of nine journals accounted for 67% of the articles (Summers, 1986). Previous studies on the special education technology literature found that 70% of the relevant literature published in a one-year period could be found in 6-11 journals (Edyburn, 2003, 2002, 2001, 2000).

What Have We Learned Lately?

The pace of change in the technology marketplace challenges scholars and practitioners to maintain their currency in the discipline of special education technology. Indeed, the question: What have we learned lately? is a difficult one to answer using the traditional tools of scholarship because of the delay between print publication and the availability of computerized indexes (typically, a nine-month delay in journals indexed in ERIC). Additionally, reviews of the literature and research synthesis articles generally do not appear in the literature until many years after a sufficient number of studies have been produced. These two factors combine to make it extremely difficult for a young discipline like special education technology to have a collective understanding of what is known. Thus, the importance of utilizing the existing knowledge base in a discipline during its formative period makes it imperative that new techniques be developed to help minimize information anxiety (Wurman, 1989) and help manage the information explosion.

An innovative strategy to address the current awareness needs of the discipline is to apply the function of research synthesis across a discipline by focusing on a single year. Rather than producing an exhaustive review of a single topic, this approach yields a comprehensive review that addresses the question, "What have we learned lately?" The results of this synthesis work contributes to the current awareness of both SET researchers and practitioners and facilitates access to the emerging knowledge base months before literature indexes are published or years before traditional literature reviews will be available. Given the recent restructuring of the ERIC system, this synthesis may serve to fill a critical knowledge utilization void.

Method

The purpose of the investigation was to conduct a comprehensive review of the scholarly literature published in 2003 in order to (a) summarize recent additions to the special education technology knowledge base informing research and practice in the field and to (b) examine the concentration, or scatter, of the literature as it is contained in professional journals. The methodology known as the comprehensive one-year research synthesis approach (Edyburn, 2000) was utilized.

Procedures

Search procedures. Three studies provided a basis for defining the search procedures. Summers (1985) conducted an early investigation into the bibliometric properties of a journal literature (i.e., microcomputers in education) using a mainframe computer to analyze ERIC bibliographic records. The present study replicates the methodology advanced by Edyburn (2000) for creating a one-year literature synthesis of the special education technology literature as a tool for maintaining current awareness in a discipline with an emerging knowledge base. Finally, an analysis for authors interested in locating journals that publish manuscripts on educational technology topics, Price & Maushak (2000) suggested that the boundaries of the discipline of educational technology may be represented in the context of 16 different journals.

The author reviewed a list of journals indexed by the ERIC system and the holdings of three local research libraries and discerned three groups of journals that could potentially publish articles relevant to special education technology: special education technology journals, special education journals, and educational technology journals. Whereas there are clearly many topics with overlapping interest within the three groups (i.e., distance education, Web-based instruction), each literature has a strong appeal to distinct groups of readers.

Special education technology journals were considered to be those that would be frequently subscribed to by professionals who consider themselves to be special education technology specialists. Five journals were identified in this category.

Seventeen special education journals were identified from among the over 50 journals referenced in the ERIC system as representing a core knowledge base in special education. While some journals have a general focus, others have a disability specific focus. For the most part, these journals are among the largest and most prestigious journals in the profession and are targeted for special education teachers, administrators, and researchers.

Educational technology journals were considered to be those that would be read by professionals who consider themselves to be educational technology specialists. Nine journals were identified in this category reflecting a subset of the work of Price & Maushak (2000) as they describe the editorial focus of 16 educational technology journal.

To locate articles that contribute to an emerging understanding of the field of special education technology, manual reviews of the table of contents of each issue of the 31 journals published in 2003 were conducted March through July 2003. Computer searches were not conducted for several reasons. First, there is a six-to-nine month time lag between when the print publication appears and when the citation is entered into the ERIC system, and the subsequent dissemination of the ERIC database update (three-to-six additional month). Second some of the core publications for the field of special education technology (i.e., *Closing the Gap, Special Education Technology Practice*), are not reviewed nor indexed by the ERIC system and therefore would not be found in computer searches. Finally, some journals are only selectively reviewed, that is, some rather than all contents are included in the ERIC indexing process.

The 31 journals reviewed in this study are listed in Table 1 along with each issue that was reviewed. Based on previous research findings (Edyburn, 2003, 2002, 2001, 2000), it was hypothesized that the highest concentration of relevant literature would be found in special education technology journals, followed by special education journals. It was anticipated that the lowest ratio of special education technology articles would be found in the educational technology literature.

Selection procedures. The author reviewed each journal issue by browsing the table of contents to identify article titles potentially of interest to researchers and practitioners in the field of special education technology. As necessary, individual articles were scanned to ascertain their relevance. Announcements, editorials, and product reviews were not counted nor were articles that focused primarily on medical or rehabilitation applications of technology.

Relevance. An article was judged to be relevant if it expressly mentioned technology (assistive, instructional, or educational) and individuals with disabilities in contexts associated with schooling or learning. This could include articles addressing student or teacher use of technology in

Table 1
2003 Journals Reviewed (n=31)

Special Education Journals (n=5)	
Title	**Issues reviewed**
Assistive Technology	15(1), 15(2)
Closing the Gap	21(6), 22(1), 22(2), 22(3), 22(4), 22(5)
Journal of Special Education Technology	18(1), 18(2), 18(3), 18(4)
Special Education Technology Practice	5(1), 5(2), 5(3), 5(4), 5(5)
Technology and Disability	15(1)
Special Education Journals (n=17)	
Title	**Issues reviewed**
Behavioral Disorders	28(2), 28(3), 28(4), 29(1)
Career Development for Exceptional Individuals	26(1), 26(2)
Education and Training in Developmental Disabilities**	38(1), 38(2), 38(3), 38(4)
Exceptional Children	69(2), 69(3), 69(4), 70(1)
Focus on Exceptional Children	35(5), 35(6), 35(7), 35(8), 35(9), 36(1),36(2), 36(3) [*see notes]
Gifted Child Quarterly	47(1), 47(2), 47(3), 47(4)
Intervention in School and Clinic	38(3), 38(4), 38(5), 39(1), 39(2)
Journal of Early Intervention	26(1), 26(2), 26(3), 26(4)
Journal of Learning Disabilities	36(1), 36(2), 36(3), 36(4), 36(5), 36(6)
Journal of Special Education	37(1), 37(2), 37(3), 37(4)
Learning Disabilities Quarterly	26(1), 26(2), 26(3), 26(4)
Learning Disabilities Research and Practice	18(1), 18(2), 18(3), 18(4)
Mental Retardation	41(1), 41(2), 41(3), 41(4), 41(5), 41(6)
Remedial and Special Education	24(1), 24(2), 24(3), 24(4), 24(5), 24(6)
Teacher Education and Special Education	26(1), 26(2), 26(3), 26(4)
Teaching Exceptional Children	35(3), 35(4), 35(5), 35(6), 36(1), 36(2)
Young Exceptional Children	6(2), 6(3), 6(4), 7(1)
Educational Technology Journals (n=9)	
Title	**Issues reviewed**
Computers in the Schools	20(1/2), 20(3), 20(4)
Educational Technology	43(1), 43(2), 43(3), 43(4), 43(5), 43(6)
Educational Technology Research & Development	52(1), 52(2), 52(3), 52(4)
Journal of Computing in Teacher Education	20(1), 20(2)
Journal of Educational Computing Research***	28(1), 28(2), 28(3), 28(4), 29(1), 29(2), 29(3), 29(4)
Journal of Research on Technology in Education	35(3), 35(4), 36(1), 36(2)
Journal of Technology and Teacher Education	11(1), 11(2), 11(3), 11(4)
Learning and Leading with Technology	30(5), 30(6), 30(7), 30(8), 31(1), 31(2),31(3), 31(4)
Technology and Learning	23(6), 23(7), 23(8), 23(9), 23(10), 23(11), 24(1), 24(2), 24(3), 24(4), 24(5)

Notes:
*Journal is behind in publication schedule.
**Name changed from: Education and Training in Mental Retardation and Developmental Disabilities
***JECR publishes two volumes each calendar year, four issues per volume (eight total annually).

Table 2.
Special Education Technology Journals

Journal Title	# of issues in 2003	total # of articles	# of articles deemed relevant	% relevant
Assistive Technology	2	16	4	25
Closing the Gap	6	23	23	100
Journal of Special Education Technology	4	25	25	100
Special Education Technology Practice	5	10	10	100
Technology and Disability	1	5	3	60
Total	16	79	65	82

special education, assistive technology, instructional technology, how-to articles, resources guides, policy or legal issues. Articles were also considered relevant if, despite not explicitly addressing individuals with disabilities, they served to inform the design, acquisition, implementation, or evaluation of educational technologies, media, materials, or methods. Again, announcements, editorials, and product reviews were not counted nor were articles that focused primarily on medical or rehabilitation applications of technology. Obviously, there is an element of judgment in this decision-making. However, given the function of the synthesis to serve as an early-alert system, an effort was made to err on the side of including all articles of potential interest to professionals working within the discipline.

Coding procedures. To ascertain the relative size of the periodic literature knowledge base for this study, as represented in the 31 journals during the year 2003, the number of total articles contained in each journal issue was recorded. Then, following the selection procedures outlined above, the number of relevant articles in each issue was recorded. Each relevant article was copied for subsequent content analysis.

Analysis procedures. Two types of procedures were used to analyze the data. To address the research question concerning the scatter of the literature, the journal titles were sorted by the number of relevant articles they contained. To address the research question concerning what was learned in 2003, the results of the search were assembled into a master bibliography and then sorted alphabetically by author's last name. Content analysis procedures were used to code of each article according to its type (i.e., development, essay, policy, practice, research, theory). One descriptor was used to describe its disability focus, if a specific disability was addressed in the article. If appropriate, one descriptor was assigned for grade/age level, and one descriptor for curriculum area. Finally, one-to-three topic descriptors were assigned to describe the focus of the work.

Results

The process of reviewing the table of contents for each issue of 31 journals published in 2003 defined a body of knowledge contained in 814 articles. After titles and articles were scanned to assess their relevance to special education technology, 28% of the total (n=224 articles), were judged to be relevant for this review. This figure is consistent (27%) with the most recent review (Edyburn, 2003).

Literature Scatter

Tables 2, 3, and 4 provide an alphabetical listing of the three groups of journals (i.e., special education technology journals, special education journals, and educational technology journals), the number of total articles, and the number of relevant articles found in each journal. While the highest concentration of relevant articles were found in the special education technology journals (82%), educational technology journals (28%) contributed more relevant articles to the knowledge base in 2003 than did special education journals (17%). As a result, the hypothesis that relevance would be distributed in concentric circles from special education technology, to special education, to educational technology journals was not supported.

One problem associated with the challenge of trying to stay current focuses on the scatter of the literature. That is, how widely does one need to read to stay current? In Table 5, the journal titles are ordered by their contribution to the knowledge base in descending order. Analysis of the literature scatter revealed that a core set of 11 journals contained 70% of the relevant articles and that 100% of the relevant literature could be found scatter among 30 different journals. While the relative ranking of a particular journal may change from year to year and may be significant influenced by special topical issues, the top two journals have remained consistent over the five years these studies have been conducted: *Journal of Special Education Technology,* and *Closing the Gap*.

Insight about the concentration/scatter characteristics of the journal literature can be gained through the application of Bradford's Law (1934). Summers (1985) describes the calculation and the interpretive framework this law affords in understanding the magnitude of a discipline's journal literature:

> Bradford's Law suggests that if the set of articles is divided into three approximately equal zones they will be

Table 3.
Special Education Technology Journals

Journal Title	# of issues in 2003	total # of articles	# of articles deemed relevant	% relevant
Behavioral Disorders	4	25	1	4
Career Development for Exceptional Individuals	2	14	1	7
Education and Training in Developmental Disabilities	4	38	9	24
Exceptional Children	4	27	6	22
Focus on Exceptional Children	7	7	2	29
Gifted Child Quarterly	4	22	0	0
Intervention in School and Clinic	5	23	3	13
Journal of Early Intervention	3	13	4	31
Journal of Learning Disabilities	6	45	6	13
Journal of Special Education	4	22	2	9
Learning Disability Quarterly	4	19	5	26
Learning Disabilities Research & Practice	4	25	5	20
Mental Retardation	6	33	5	15
Remedial and Special Education	6	30	13	43
Teacher Education and Special Education	4	22	4	18
Teaching Exceptional Children	6	53	4	8
Young Exceptional Children	4	12	5	42
Total	77	430	75	17

distributed across the journals proportionately such that the ratio 1: n. n^2 ...n^{10} will hold where 1 is the number of journals in the first zone and n is a proportional multiplier. Thus, there is always a small nucleus of journals which contains a large number of articles—usually about one-third of the total. A second larger group accounts for another third of the total, and the last very large group of journals contributes the final third. (p. 7)

To apply Bradsford's Law to the data listed in Table 5, lines could be drawn dividing the listing into three approximately equal groups (33%, 66%, 100%). Visual inspection reveals that three journals contribute 32% of the literature, seven additional journals add articles that contribute to a cumulative total of 66% of the relevant literature, and 22 journals contribute the remaining 34% of the literature. In this study, a multiplier cannot be found to explain the relationship among the three groups (3:7:22). The significance of this anomaly may be understood through the work of Brookes (1968) who observed that deviations in the first zone are most likely to occur among the most productive journals within the inner nucleus; thereby suggesting a core effect. Thus, while researchers and practitioners may perceive the literature on special education technology to be widely scattered, in reality, it is scattered less than can be predicted using bibliographic models. Indeed, the finding of a high concentration of relevant articles in a small number of journals, 32% in three journals and 70% in 11 journals, offers strong evidence concerning a core literature within the discipline.

Table 4.
Educational Technology Journals

Journal Title	# of issues in 2003	total # of articles	# of articles deemed relevant	% relevant
Computers in the Schools	4	28	9	32
Educational Technology	6	58	12	21
Educational Technology Research & Development	4	18	2	11
Journal of Computing in Teacher Education	2	9	1	11
Journal of Educational Computing Research	8	44	11	25
Journal of Research on Technology in Education	4	22	9	41
Journal of Technology and Teacher Education	4	24	4	17
Learning and Leading with Technology	8	70	24	34
Technology and Learning	11	32	12	38
Total	51	305	84	28

Table 5.
Journals ranked by the number of articles contributed to the 2003 special education technology knowledge base

Title	# of relevant Articles	cumulative	journals total	percent
Journal of Special Education Technology	25	1	25	11
Learning and Leading with Technology	24	2	49	22
Closing the Gap	23	3	72	32
Remedial and Special Education	13	4	85	38
Educational Technology	12	5	97	43
Technology and Learning	12	6	109	49
Journal of Educational Computing Research	11	7	120	54
Special Education Technology Practice	10	8	130	58
Computers in the Schools	9	9	139	62
Education & Training in Developmental Disabilities	9	10	148	66
Journal of Research on Technology in Education	9	11	157	70
Exceptional Children	6	12	163	73
Journal of Learning Disabilities	6	13	169	75
Learning Disability Quarterly	5	14	174	78
Learning Disabilities Research & Practice	5	15	179	80
Mental Retardation	5	16	184	82
Young Exceptional Children	5	17	189	84
Assistive Technology	4	18	193	86
Journal of Early Intervention	4	19	197	88
Teacher Education and Special Education	4	20	201	90
Teaching Exceptional Children	4	21	205	92
Journal of Technology and Teacher Education	4	22	209	93
Technology and Disability	3	23	212	95
Intervention in School and Clinic	3	24	215	96
Educational Technology Research & Development	2	25	217	97
Focus on Exceptional Children	2	26	219	98
Journal of Special Education	2	27	221	99
Behavioral Disorders	1	28	222	99
Career Development for Exceptional Individuals	1	29	223	99
Journal of Computing in Teacher Education	1	30	224	100
Gifted Child Quarterly	0	31		

What Did We Learn in 2003?

The review process yielded a corpus of 224 articles contributing to the 2003 knowledge base of research on special education technology. Appendix A provides a list of each article included in this synthesis of the literature. The articles are listed in alphabetical order along with an identification code which will be used in the following sections as a short-hand reference for each work.

The fundamental question of what we learned in the past year may be viewed from multiple perspectives, possible answers could focus on ways of knowing (i.e., research, practice, essay, etc.), disability specific applications, classroom applications (i.e., age/grade, subject areas), as well as through the lens of technology topics. Each view provides a number of access points to the literature and will be described in the subsequent sections.

Each article was classified as to its type (i.e., essay, research, practice, etc.). As illustrated in Table 6, the most common type of article found in the literature focused on practice. However, when all the categories involving inquiry are combined, the number of research articles (n=85) and the number of practice articles (n=79) are roughly equivalent. Overall, the special education technology literature is characterized by an emphasis on practical issues rather than research efficacy. A significant finding in 2003 is a dramatic increase in the number of articles with a historical or retrospective perspective (n=11) due to a number of journals celebrating publishing milestones (e.g., 20 years).

A second perspective for understanding what we have learned lately involves an examination of the specific disability focus in the literature. Table 7 summarizes the specific disabilities referenced in the articles in this review.

Table 6.
Articles Classified by Type

Type	Article Number
essay	12, 25, 32, 46, 57, 71, 83, 158, 159, 179, 184, 187, 188, 195, 197, 201, 205, 209
historical	2, 23, 86, 99, 131, 174, 214, 216, 217, 219, 220
literature review	19, 21, 35, 36, 41, 44, 47, 51, 87, 95, 124, 149, 151, 154
meta analysis	113, 156
policy	5, 43, 128, 186, 192, 212
practice	1, 3, 4, 8, 13, 18, 20, 22, 24, 29, 31, 38, 48, 53, 54, 55, 56, 58, 64, 65, 66, 67, 69, 70, 72, 73, 74, 75, 77, 78, 79, 81, 84, 89, 90, 92, 93, 94, 98, 100, 103, 104, 105, 107, 108, 114, 116, 117, 120, 122, 136, 139, 140, 141, 142, 144, 155, 157, 165, 166, 167, 170, 175, 178,180, 181, 182, 183, 190, 196, 198, 202, 207, 208, 211, 218, 221, 222, 223
research	
accessibility	161
action	26, 194
case study	111, 129
measurement	203
development	27, 30, 63, 85, 102, 112, 132, 133, 162
economic valuation	76
group comparison	14, 17, 62, 101, 106, 115, 127, 130, 134,138,153,163, 171, 176, 177, 206
instrument validation	86, 135, 168
program evaluation	7, 10, 15, 16, 34, 39, 40, 45, 68, 109, 110, 137, 143,145, 150, 152, 169, 172, 189, 200, 210, 224
qualitative	33, 60, 118, 213
research agenda	173
research synthesis	123, 185
research utilization	6, 37, 97, 125, 199
single subject	28, 61, 82, 126, 148
survey	9, 42, 59, 80, 91, 146, 147, 160, 164, 193, 215
theory	11, 49, 50, 52, 88, 119, 121, 191, 204

The three most common disability groups in the special education technology literature are communication disorders, learning disabilities, and mental retardation; all high incidence disabilities. It is interesting to note that only 23% of the articles (n=52) explicitly reference the application of the work to a specific disability. This may be due to the increasing emphasis on generic applications (i.e., universal design, Web searching) that are useful for learners of all ages and abilities. In other cases, when a specific disability is not mentioned in the article, the reader is expected to provide the bridge between understand the application of the technology to the students s/he works with.

As one might expect, many articles in the special education technology literature focus on classroom applications of technology for students with disabilities. As noted in Table 8, articles can be found at all levels of education. However, the majority of the articles (50%, 29/58 articles) focus on PreK – Grade 8 applications. A disproportionate number of post-secondary applications can also be noted (22%, 13/58 articles). The specific curriculum focus of the articles, if applicable, is listed in Table 9. The three most common curriculum applications of special education technology were found in reading, writing, and math.

A final lens for understanding what we have learned lately involves examining the topics within each article. For this purpose, each article was assigned one-to-three descriptors. Table 10 provides an alphabetized list of topics found in the 2003 journal literature. Content analysis of the relevant articles revealed a number of dominant themes in the literature during 2003: assistive technology, implementation issues, instructional design, instructional strategies, outcomes of technology, professional development, reading and technology, and technology integration. As might be expected, a number of other topics are well represented in the literature: augmentative and alternative communication (AAC), accessibility, assessment, evidence-based practice, inclusion and technology, universal design, Web resources, and Web-based instruction.

Of particular interest to the special education technology community are new developments in access to the curriculum (#1, #18, #48, #144, #183, #212, #213); test accommodations (#186, #211) the value and use of blogs for writing (#24, 103, #104); insights about intellectual property, copyright laws, and the ever-changing boundaries of fair use (#12, #128); and federal policy initiatives in the form of No Child Left Behind (#19, #88, #92, #140, #180, #190), the

Table 7.
Articles by Disability Focus

Disability	Article Number
autism	75
communication disorders	7, 84, 85, 89, 126, 158, 159, 178, 179, 195, 208
deaf	157
dyslexia	101
emotional/behavioral disabilities	151
high incidence disabilities	68
HIV/AIDS	105
homebound	16
learning disabilities	6, 21, 28, 44, 80, 97, 123, 154, 199, 205
mental retardation	39, 40, 61, 62, 82, 212, 213
mental retardation/ developmental disabilities	41
mild disabilities	15, 134, 188
moderate, severe disabilities	119, 143
physical and learning disabilities	200
physical impairments	100, 135, 219
print disabilities	90
severe disabilities	18
significant disabilities	19, 29, 203
stroke	34
visual impairments	122

National File Format (#192), and the National Education Technology Plan (#173). At an indiscernible level it is interesting to perceive a pattern of concerns about functions associated with choice making (#136), independence, (#29, #40, #204), and quality of life (204). A developmental sign the discipline may be maturing can be seen in articles addressing important professional issues such as assessing the prestige of technology journals (#91), the impact of technology work in promotion and tenure decisions (#71, #91, #215), and pending shortage of doctoral level leadership personnel (#164). Finally, for professionals interested in issues of diversity and technology, it continues to be disconcerting to observe the limited effort that has been devoted to issues of cultural sensitivity (#8, #70, #162), equity (#216), gender differences (#130, #176, #177).

Discussion

As a strategy to simultaneously address the problem of information overload and to provide scholars and practitioners with new tools for accessing the extant knowledge base, this study utilized an innovative research synthesis methodology to create a comprehensive one-year review of the literature exploring two questions: How widely scattered is the literature on special education technology? and What did we learn in 2003?

Table 8.
Articles by Grade Level

Grade Level	Article Number
preschool-K	7, 67, 106, 126, 136, 144, 169, 185
preschool-1	115
preschool-8th grade	135
preschool-12th grade	54, 58
kindergarten	47
K-5th grade	3
K-8th grade	113
elementary	
grades 1-3	206
grades 1-6	31
grades 2-3	153
grades 3-6	130
grade 4	86
grades 4-5	148
grades 5-7	127
grades 6-12	28, 82, 143
grades 6-9	213
grade 8	176, 177
grades 8-10	61
secondary	
grade 9	171
grade 9-adult	152
grade 10	33
grades 9-12	6, 15, 44, 95, 129, 134, 194, 199
post secondary	4, 10, 25, 80, 118, 123, 154, 163, 184, 189, 193, 218, 224
adult	16, 34, 39, 40, 62

Literature Scatter

The problem of literature scatter is one that confronts all researchers and practitioners as they face the daunting task of trying to stay current in their discipline. The interdisciplinary nature of the field of special education technology may also reinforce a perception that the literature is widely scattered among many journals. However, the findings of this study reveal it is not scattered as widely as would be predicted by bibliographic models (Bradsford, 1934). In fact, the results offer strong evidence concerning the presence of a core literature within the discipline given that 70% of the relevant literature can be found within 11 journals.

For the past two years, the hypothesis that the literature would be organized in concentric circles with the most relevant articles being found in a core of special education technology journals, followed by special education journals, and finally educational technology journals was not supported. It appears that this may be due in part to the inclusion of a greater number of articles from educational technology journals which have grown at a greater rate (2003, 28%; 2002, 24%, 2001, 14%)

Table 9.
Curriculum Focus (if applicable)

Curriculum Focus	Article Number
career exploration	152
fine arts	167
functional curriculum	119, 126, 143
history	44
homework	58
hypermedia	33
language arts	171
literacy	12, 103
math	14, 28, 30, 52, 95, 113, 115
money	39, 40
play	7, 185
positive behavior supports	82
problem solving, writing	127
reading	46, 48, 54, 78, 79, 98, 101, 106, 114, 122, 138, 141,153, 156, 169, 206
reading, math	203
science	22, 31
social behavior	61
social skills	67
social studies	3, 134, 137
vocabulary	21
writing	24, 47, 50, 65, 66, 68, 97, 104, 123, 135, 149, 200, 207
writing, math	148

than the articles included from special education journals (2003, 17%; 2002, 17%, 2001, 15%).

The impact of the literature scatter findings (see Table 5) can be assessed in several ways. For the practitioner, the results help answer questions like, "How much do I need to read to stay current?" and "How widely do I need to read?" The list helps an individual set priorities for reading and offers a confidence measure of how much coverage of the literature they are encountering. For librarians and resource organization, the results contribute to efforts related to collection development. That is, which journals should be included when building a special education technology collection? And, what is the cost of maintaining annual subscriptions to a comprehensive collection of journals covering the discipline of special education technology? Similarly, individuals may wonder, "If I can only afford a few journals, are there some that are more relevant than others?" Researchers can utilize the information on literature scatter when planning manual or computer-based literature searches. Authors might use the findings to inform decisions about where to publish a specific manuscript on special education technology. Finally, editors might use the findings to study the relative rankings of their journal from year to year to assess whether or not technology coverage is above average, average, or below average compared with other journals.

What Did We Learn in 2003?

The second research question addressed by this study sought to address the question, What have we learned lately? (and more specifically: What did we learn in 2003?). While the results are necessarily limited due to the one-year sample, a number of insights are possible. First, more information about issues of practice in special education technology are published than research. Largely, this may be a function of the publication cycles of the practice-oriented journals (e.g., *Closing the Gap,* six times annually; *Special Education Technology Practice*, five times annually; *Learning and Leading with Technology,* eight times annually) versus research journals which are typically published quarterly. Second, more articles are published which have application across disabilities rather than are published for any specific disability. Third, more articles are published which have PreK – grade 8 applications than are published for any specific age/grade level. Interestingly, there appears to be an over-abundance of articles on technology use in post-secondary education, which may suggest a reliance on convenience samples (i.e., World Wide Web applications and preservice teachers). Fourth, most articles with a curriculum emphasis focus on reading, writing, math. Given the emphasis on reading achievement in No Child Left Behind, perhaps it is not surprising to find a 229% increase in the number of articles devoted to reading and technology in 2003 (n=16) versus 2002 (n=7). Finally, content analysis of the relevant articles revealed a number of dominant themes in the literature during 2003: assistive technology, implementation issues, instructional design, instructional strategies, outcomes of technology, professional development, reading and technology, and technology integration (see Table 10).

Limitations of the Study

Several limitations of the current work should be noted. Whereas this study only reviewed literature published during a one-year period, the results may vary during other time periods given the significant impact a special topical issue has on the rankings. Second, development of additional classification indices would standardize the topical descriptors and increase the number of access points for locating specific articles of interest. Finally, it must be noted that the selection process is inherently subjective. To the extent that the process works, it reflects the author's knowledge of the discipline and critical issues. At the same time, bias (intentional or unintentional) is likely to impact the inclusion and exclusion of works that other reviewers may find relevant.

Implications for Future Research

While portions of the methodology in this study have been utilized by other researchers (Mason, Thormann, O'Connell, & Behrmann, 2004), additional research is

Table 10.
Articles by topic (1-3 descriptors per article)

Topic	Article Number
21st century skills	120, 180, 181
AAC	7, 82, 84, 85, 89, 126, 178, 208
academic performance	80, 148, 151, 194, 203, 204, 213
academic supports	25, 193
access control panels	108
access to the general curriculum	1, 18, 48, 144, 183, 212, 213
accessibility	12, 93, 108, 160, 161, 192, 201
accommodations	80
acquisition of technology	118
adapted books	122
administrative training	42, 92, 141
agents	10
alternative assessment	18, 19, 203
animation	10, 169
assessment	41, 137, 139, 149, 165, 169, 186, 205, 211
assistive listening devices	157
assistive technology	4, 43, 45, 50, 51, 57, 60, 76, 80, 88, 96, 100, 105,116, 123, 147, 154, 157, 193, 194, 200, 218
assistive technology consideration	43, 57, 84, 154
assistive technology focus groups	162
assistive technology for learning	3
assistive technology services	59, 221
assistive technology use	59
ATM computer simulation	39
audio texts	15
authoring	30
automated essay scoring	149
balanced literacy	46, 79
blogs	24, 103, 104
Braille	75
Bobby	93, 161
CDROM	15, 152
choice making	136
clinical psychology	41
cochlear implants	157
cognitive simulations	102
collaboration	201
competencies	116
computer access	16, 135
computer assisted instruction (CAI)	21, 30, 101, 106, 113, 115
conceptual models	121
copyright	12, 128
cost	5, 76
creative software	167
cultural sensitivity	8, 70, 162
Dana	65, 66
databases	198, 207
data mining	139, 140
decision making	32
decision support systems	109
diffusion of innovation	60
digital audio	90
digital divide	216
digital text	12, 13, 75, 98
digital video	132
distance education	71, 114, 124, 145, 181, 197, 222
doctoral faculty shortage	164
DraftBuilder	68
early intervention services	5
electronic portfolio	81
email	16
email mentoring	224
evidence-based practice	7, 84, 85, 198
environmental control	155
equity	216
expert systems	102
facilitated communication	158, 159, 179, 195
families	8, 162
functional behavior assessment	163
functional communication behavior	20
gender gap	130, 176, 177
graphic organizers	95
home computer use	130
home-school communication	58
hypermedia	191
HyperStudio	167
hypertext	138
implementation issues	36, 63, 65, 66, 73, 74, 81, 110, 170, 175, 178, 190,196, 223
inclusion and technology	105, 126, 142, 144, 171, 183
independence	29, 40, 204
individualized education programs (IEPs)	186
information retrieval	77, 177
instructional design	4, 10, 17, 22, 32, 33, 39, 40, 94, 102, 112, 117, 119,130, 138, 143, 152, 182, 184, 191
instructional effectiveness	83
instructional modifications	148
instructional strategies	6, 15, 22, 31, 47, 97, 199
instructional technology	51, 217
intellectual property	128
international technology use	111
interactive video	222
interactive whiteboard	142
job accommodations	129
JumpStart	115
KidPix	167
knowledge management	27
laptop computers	127
latent semantic analysis	149

Table 10.
continued

learning environments	94, 182, 185, 191
learning from text	54, 134
legal issues	43, 128
manipulatives	28
measurement	172, 210
Microsoft Word's track changes	223
Millie's Math House	115
model computer classroom	94
monitoring student progress	170
mounting	89
multimedia	44, 143
National Education Technology Plan	173
National File Format (NFF)	192
National Technology Standards	9
navigational strategies	135, 176
No Child Left Behind (NCLB)	19, 88, 92, 140, 180, 190
notetaking	134
offline web page use	38
online community	16
online survey tools	202
online video conferencing	187
online publishing	104
open source	23
Open Video Project	132
outcomes of technology	3, 36, 37, 49, 50, 52, 68, 76, 121, 123, 126, 160,172, 198, 210
PDAs	1, 175
performance of personal stories	208
powered wheelchairs	219
PowerPoint	67, 107
predictive word processor	200
preservice teacher education	81, 147, 163, 167, 189, 218
project-based learning	33
project management	74
prestige of technology journals	91
promotion and tenure decisions	71, 91, 215
professional development	26, 29, 35, 42, 45, 51, 56, 79, 83, 99, 110, 114, 124,125, 146, 147, 150, 174, 181, 221, 222, 224
professional productivity	27, 41, 71, 109, 215
quality of life	204
readability tools	78
Reading First	141
reading and technology	54, 78, 90, 98, 101, 106, 138, 153, 156, 169, 206
return on investment (ROI)	210
remediation vs. compensation	48, 54
research methods	36, 37, 47, 124, 145, 151, 152, 162, 173, 179
response to intervention (RTI)	205
robot-mediated therapy	34
scaling up	110
scientifically based interventions	125
scholarly publishing	13, 91
scoring guides	165
single switches	100
software	40, 99
sources of information about AT	59
speech recognition	153
speech-to-text	60
standards	120, 180, 194
streaming audio	90
student performance data	140
student research	53, 77
supply and demand	164
tactile experience books	122
technology acquisition	139, 166, 175
technology adoption	21, 23, 96, 131, 209, 214, 217, 220
technology enhanced performance	11, 57
technology integration	4, 9, 42, 64, 69, 79, 111, 127, 150, 160, 168, 173,178, 179
technology leadership	72, 73, 74, 190
technology planning	64, 112, 166
technology-rich student projects	117
test accommodations	186, 211
text modifications	48, 54
thematic units	69
transition	25, 129, 154, 193
universal design	25, 31, 93, 183, 184
video clips	62
video feedback	61
video self modeling	87
video-based instruction	171
video-based problem solving	14
videodiscs	14
Virtual Assistant	1
vision	72
visual supports	17, 67, 107
vocational rehabilitation counselor	118
voice recognition	155
web resources	53, 58, 69, 92, 98, 117
web accessibility guidelines	161
web searching	53, 77, 86, 176, 177
web-based certification courses	197
web-based computer games	137
web site classification system	133
web site development	63
web-based instruction	32, 35, 38, 112, 163, 188, 207
web page authoring	38, 78
wireless computing	196
WYNN	68

needed in two areas. First, the value of the comprehensive one-year research synthesis needs to be established from a user's perspective. That is, does the synthesis provide access to the extant knowledge base in ways that are perceived useful by scholars and practitioners? Does it save time? Does it direct users to resources that are highly relevant for their needs? Second, given the five year data set produced from through the annual reviews, is it possible to discern what we need to know? That is, are there critical omissions that could be highlighted to suggest individual or collective research agendas?

Implications for Development

Development of additional tools in conjunction with the vision outlined by Willinksy (1999) seems appropriate to consider as scholars and practitioners struggle to exploit knowledge within the extant database. Certainly the current context of No Child Left Behind demands increased research and development efforts associated with knowledge utilization. The recent restructuring of the ERIC system has created a void at the very time demands for scientifically-based interventions have escalated the need for tools to access and utilize the professional knowledge base.

For example, consider the possibility of a Web-based system where scholars or practitioners sign-on and complete a brief profile of their interests and preferences for document delivery. Using simple algorithms or sophisticated software or Web-based agents, the bibliography generated in this study could be used to identify appropriate reading materials for the user. A document delivery system could then forward the information in the medium (i.e., print, PDF, html, text-to-speech) at the specified time (i.e., Friday afternoons). Such a system could also be linked with a competency framework to deliver readings that lead to specified professional development knowledge and skills, linked to an electronic quiz system to test one's understanding of each reading, and provide a digital diary to document the time engaged in professional development activities in order to subsequently issue credit or continuing education units (CEUs). Clearly, the field of special education technology needs to explore the development of these types of visions and scenarios.

Implications for Practice

The scope of this review synthesizes information in journals beyond what the average professional probably has time to read on a regular basis. The finding of over 220 relevant articles suggests the need to learn more about the professional development habits of special education technology professionals as it relates to reading and using new knowledge. To stay current in the year 2003, this study suggests the need to set aside time each workday to read one article. However, how often is this done? Can electronic document delivery services help assist in the process of staying current by providing relevant new readings on a regular basis?

The results also provide a basis for generating an economic analysis of the cost (i.e., subscriptions to each journal) to build and maintain a scholarly library supporting the discipline of special education technology. This type of work is common in bibliometric analysis and will yield practical information for individuals maintaining a personal library, university libraries trying to maintain a research-quality journal collection, as well as resource agencies that need to balance priorities and budget.

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APPENDIX A

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