Computer Technology, Science Education, and Students with Learning Disabilities

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The ways computer technology could be used to teach science to students with learning disabilities (LD) are explored. Science is for all students and that includes students with LD. Learning science has both cognitive and affective implications for students with LD. In this context, computer technology provides cognitively engaging and motivating instructional tools for individualizing the mode of delivery; developing expert tutors; anchoring instruction; integrating science with other subjects; reducing cognitive load on working memory; and motivating students to stay on task. These applications are discussed with implications for teaching science to students with LD.

KEY WORDS: Science; learning disability; computer technology.

INTRODUCTION

This paper will explore ways of improving the quality of science education for students with learning disabilities (LD) using computer technology. According to national science organizations such as the American Association for the Advancement of Science (1989), K-12 science education should benefit all students. Holahan, McFarland, and Piccillo (1994), in a summary of studies by Gregory, Shahan, and Walberg (1985); Ysseldyke, Thurlow, Christenson, and Weiss (1987); Harnish and Wilkinson, 1989; Patton, Polloway, and Cronin (1990)) reported the following picture of science education for students with disabilities. Among high schoolers, students with disabilities scored significantly lower grades on science tests than students without disabilities. The instructional time devoted to students with mild disabilities in science was less than that in reading. About 42% of special education teachers had no science training and 38% of children in self-contained classes received no science instruction. Less than 60 minutes per week was devoted to teaching science by half the special educators who teach science. As Holahan, et al. (1994) stated, despite calls for making science beneficial for "all," very little effort has been made to make science available to students with disabilities.

One potential tool for making science available to all students is computer technology. For example, the electronic "information super highway" is capable of bringing scientific information to the fingertips of all learners and teachers in the U.S. While these efforts are purported to be improving the quality of science education for all, they are often biased and serve only the average pupils, referred to as the "normal students." Unfortunately, very little has been done with respect to improving the quality of science education to meet the needs of students with disabilities.

Students with Learning Disabilities

In defiance of normal intellectual functioning, students with LD exhibit academic deficits that impede their progress in the general education classroom. While they have the same needs as other students, their access to creative and challenging learning opportunities often is impaired. Their deficient skills in the basic areas affect their abilities to

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understand and enjoy learning in the sciences. For example, these students may find it difficult to read content-area textbooks, listen and take notes in class, produce coherent written work, or take tests. Furthermore, they may lack the experiences, vocabulary, and study strategies necessary for school success. Yet, most teachers rely on lectures, textbooks, and written tests as the primary means of delivering and evaluating instruction in content-area classes such as science. Even when students with LD are able to get passing grades in their general education content-area classes, such as science, they still receive lower grades than do their low-achieving peers. For example, Donahoe and Zigmond (1990) found that ninth-grade youngsters with LD received lower grades than did their low-achieving peers in the same general education social studies and health classes and 69% of ninth-grade students with LD earned a D or below in science.

Additionally, research has shown that LD students are generally slower in executing basic mathematics problems; this poses a deficit that could impede their progress in science (Goldman, Pellegrino, and Mertz, 1988). According to one study (Goldman et al., 1988), such deficiencies, at least in mathematics, are largely due to delayed learning as opposed to developmentally different reasoning from normal students. Therefore, the skills and reasoning strategies of students with LD have been found to be largely the same as normal students, but they occur at later ages.

A large portion of the energy of students with LD is focused on the solution of simple tasks; thus, less cognitive energy is available for the development of the complex reasoning skills required in science. These same students often have low self-esteem and low motivation associated with prior frustrating learning experiences. Technological tools such as those described in this paper contain several unique features that address the aforementioned concerns.

Why Science Education for Students with Learning Disabilities?

There are two major reasons for providing science education for students with LD. The first reason is constitutional and the second pedagogical. The Americans with Disabilities Act (ADA), often referred to as the “most comprehensive civil rights legislation since the 1960s” (Stinson, 1993, p. 71), along with the Individuals with Disabilities Education Act (IDEA), give the constitutional justification for providing access to science education for all students. Therefore, it is not out of charity that students with LD be provided as solid an education as those without LD, but it is the legal right of students with LD that they must be given access to all available educational opportunities in the United States.

From a pedagogical perspective, science is a subject which is cognitive and affective in nature (Lawson, 1994; Simpson, Koballa, Oliver, and Crawley, 1994). Science is a subject quite suitable for developing thinking and problem solving skills and enhancing the affective attributes, such as better attitude towards the world among students with disabilities. In effect, science is both hands-on and minds-on in practice. As Aldridge (1992) said, “science is needed by everyone and everyone [including those with LD] is capable of learning and enjoying science” (p. 14). However, with the existing traditional instructional practices such as lecture, teacher demonstration and rote learning, it is difficult to make science interesting and appealing to students with LD. This present condition of a lack of opportunities for involvement of students with LD in science education is obvious when Reith and Polsgrove (1994) opined that there is very little emphasis on science education in special education. On the other hand, considering the advantages of science education mentioned earlier, it is critical to search for alternative instructional tools for teaching science to students with LD. In this context, how computer technology could be used to deliver science education and make science more appealing to students with LD is worth exploring.

An examination of the literature in science education, technology education and special education revealed that scant attention was given to how computer technology could be used to deliver science education to students with LD. A search of the Educational Resource and Information Center (ERIC) database showed that there was a paucity of published studies discussing and/or presenting computer-assisted instruction as one of the effective intervention techniques for making science education a meaningful experience for students with disabilities. Therefore, other more direct sources of information were consulted for this paper.

The Role of Computer Technology

Computer technology is gaining wide acceptance in science teaching and learning. Interactive videos,
hybrid multimedia environments, and virtual reality are replacing earlier educational computing applications like low level drill and practice software. These newer technologies have not only improved the quality of computer applications in education, but also provided a basis for understanding human cognition and learning. Using computer environments for teaching science to students with disabilities has both cognitive and affective implications. Computer technology could provide cognitively challenging environments for the development of analytical, critical thinking, reasoning and problem solving skills in students. Also technology could provide students with interesting and motivating learning experiences that would help them to stay on task. Using computer technology, science educators and researchers can facilitate the teaching of science to students with learning disabilities through: individualizing the mode of delivery; developing expert tutors; anchoring instruction; integrating science with other subjects; reducing cognitive load on working memory; and motivating students to stay on task. Further discussion will highlight these instructional attributes of computer technology with reference to students with LD.

**Individualizing the Mode of Delivery**

Textual information may often not be appreciated by students with LD. In this respect, computers are ideal tools for individualizing the mode of delivery of presentation and style of interaction (Hythecker, Rocklin, Dansereau, Lambiote, and O'Donnel, 1985; Bristor and Drake, 1994; Lovitt and Horton, 1994). For example, in biology lessons, students may be presented with the option of choosing information in the form of text, still pictures or videos depending upon his/her individual level of attention and comprehension. Hypermedia software such as HyperCard (TM) and Linkway (TM) provide enormous opportunities for improving presentation modes to suit the individual needs of learners.

These computer tools have the potential for providing additional support for students when learning through the use of multimedia involving audio (e.g., pronunciation and explanation of words) and animation and video to demonstrate complex concepts. Multimedia presentations are highly visual in nature, providing step-by-step highly pictorial instruction rather than prose. Because of students' impaired learning abilities, a teacher cannot always assume students have read and understood traditional laboratory science instructions. Therefore, students with impaired reading or math skills are less disadvantaged than they might be in a traditional science curriculum. For example, in a study involving students with LD, Higgins and Boone (1990) found that those students who received hypertext-based instruction scored the highest on a daily quiz compared to those who received lecture and lecture plus hypertext-based instructions. Through the use of flexible hypertext instructional tools that emphasize simple, sequential, and pictorial instructions, teachers can be more assured that students are understanding the instructions given. In addition, students have the power to re-run, retest, or practice ideas as often as they wish, and at a time of their choosing. Individuals can work at their own pace through a lesson doing whatever level of work their learning allows.

**Developing Expert Tutors**

In traditional classroom settings it may be practically impossible for a teacher to give individual help or attention to students with LD. With computer technology, it is possible to develop expert tutors to provide higher cognitive level learning experiences on an individual basis. Expert tutors are known to improve student thinking and problem-solving skills to the level of the experts modelled by the tutor (Lajoie and Lesgold, 1989; Dori, Dori, and Yochim, 1992). For example, Lajoie and Lesgold (1989) described "SHERLOCK," a computer-based tutor to train Airforce trainees in troubleshooting. Novice trainees who used SHERLOCK were able to perform at a level equal to that of their colleagues with four more years of on-the-job experience.

Advantages of expert tutors for students with LD include the ability of expert tutors to present instruction in small sequential steps for problem solving, to provide variable levels of difficulty and review of concepts, and to allow students to work independently (Bos and Vaughn, 1994). However, critical to the success of expert tutors used by students with LD is the analysis of student performance and use of effective instruction (Bos and Vaughn, 1994). The program should provide the student and teacher with specific corrective feedback. For applications of expert systems for the diagnosis and treatment of learning problems please refer to Hofmeister and Lubke (1988) and van Geldern, Ferrara, Parry, and Rude (1991).
Anchoring Instruction

"Anchored instruction" is an instructional technique where videodiscs of real world problem situations are used as "anchors" to provide a macro context for students to gain a meaningful understanding of the topic they learn (Cognition and Technology Group at Vanderbilt, CTGV, 1990). According to Bransford, Sherwood, Hasselbring, Kinzer and Williams (1990), "the major goal of anchored instruction is to enable students to notice critical features of problem situations and to experience the changes in their perception and understanding of the anchor as they view the situation from new points of view" (p. 135). In this respect, the use of videodiscs helps students revisit problem situations and overcome "inert knowledge," that is the knowledge people possess but often fail to recall spontaneously for problem solving due to a lack of meaningful context (Whitehead, 1929).

The potential to provide students with an array of concrete visual representations of concepts and relationships through the use of videodiscs is particularly promising for teaching students with learning problems (Hofmeister, Engelmann, and Carnine, 1989). The images can be presented in slow motion, fast motion, or frame by frame allowing students with LD to critically view (and review as necessary) the features of problem situations at their own learning pace. The ability to store and randomly access large amounts of information is an added advantage.

Integrating Science with Other Subjects

Computer technology is an ideal tool for removing the barriers that separate science and other disciplines such as language arts and reading. Integrating science with other disciplines has cognitive and affective implications, because integrated approaches to instruction demand the use of both the right and left brain hemispheres (Fortner, 1990). Thus, for example, students with LD are encouraged to use their linear and non-linear metaphoric ways of thinking leading to meaningful understanding of the concepts and principles discussed in science courses. The multiple mode of presentation of information using multimedia can help students to see any information beyond the boundaries of subject matters. Bristor and Drake (1994) reported a five year study of integrating science and language arts in which they have employed several modes of information presentation with the aid of technology.

Science telecommunications networks provide excellent opportunities for integrating science with other disciplines. Student enthusiasm for Kids Network (a science telecommunications network) resulted in student-initiated activities of writing to other students at different lab stations, bringing in newspaper clippings, verifying data through comparison with supplemental professional data, and improved collaborative writing of reports via word-processing packages (Tinker, 1987). For students with LD, science telecommunications networks can give "expanded access to the physical and social world, bringing it closer to them—even if indirectly—to be examined as it has not been before" (Cuffaro, 1984, p. 565).

Reducing Cognitive Load on Working Memory

Students with LD experience difficulties doing mental operations involving several variables at a time. Thinking and problem solving involving more than one variable at a time is a skill necessary for survival in science at higher grade levels, and might pose a problem for students with LD due to their limited working memory. Computers have been credited with functioning like an external human memory, and thus believed to be reducing the load on working memory in situations involving computer interactive learning and problem solving in science (Champagne and Klopfer, 1984; Kumar, White, and Helgeson, 1994a). For example, in a study of novice and expert high school chemistry students solving stoichiometric problems Kumar, et al. (1994a) found that novice students using computers performed at a level similar to expert students using the paper-and-pencil method. In a physics problem-solving experiment Staver (1986) found that the performance level of students increased as the number of independent variables was decreased, leading one to believe that the amount of memory space required to think while solving a problem has direct consequences on the outcome. Considering this view point in light of the poor working memory students with LD possess, it could be constructively argued that computers have a lot to offer in aiding their working memory via interactive computer tasks. In this context, the role of innovative input devices such as induction pen (used in pen-point computers) in reducing the human-computer interaction at the cognitive-psychology-com-
puter-technology interface (Kumar, Helgeson, and White, 1994) should not be overlooked. Input devices like the induction pen might improve the performance of students with LD in computer interactive problem-solving tasks in science by enabling them to better convey their cognitive processes than traditional paper-and-pencil methods.

Motivating Students to Stay On Task

Computers are excellent motivational tools to keep students on task. According to Jackson (1988), computer features such as immediate formative feedback to students about their performance play a significant role in motivating students to stay on task and complete their assignment. In a study, Kumar, et al. (1994a) noticed that the time-on-task for the novice chemistry problem solvers using computers was significantly higher than their counterparts using traditional paper-and-pencil method.

Maintaining attention on learning tasks is often a problem for students with LD. Lack of attention frequently leads to impaired and frustrated learning. Teaching strategies that can encourage students with LD to remain interested and working are therefore especially beneficial. For example, students with LD often remain more cognitively engaged when using technological tools than without them, particularly when corrective feedback is immediately provided (Goldenberg, Russell, and Carter, 1984).

SUMMARY

A few ways computer technology could be used to facilitate the teaching of science to students with LD from that of rote practice to higher level thinking have been presented in this paper. They include individualizing the mode of delivery, developing expert tutors, anchoring instruction, integrating science with other subjects, reducing cognitive load on working memory, and motivating students to stay on task. The salient features of each of these were discussed.

The instructional attributes of computer technology discussed in this paper have tremendous potential to improve the cognitive and affective aspects of science education for students with LD. Authoring systems and multimedia permit teachers and students to prepare individualized lessons and examinations. The capabilities for individualizing instruction using technology can not only lead to engaged learning but also to more meaningful knowledge acquisition (Songer, 1989; Tinker, 1987). Expert systems and anchored instruction provide opportunities for simulations that emphasize problem-solving abilities and the development of knowledge. Application systems such as word processing and database management are ideal for the integration of science with other disciplines and allow students to be active planners and communicators. Learning environments containing multiple sources of information and multiple viewpoints can be provided for student exploration and integration into a personal construction of meaning. In effect, active participation of students with LD in science using technology exposes them to meaningful learning and enables them to appreciate science, and could result in more students with LD making science a possible career choice.

Additionally, computer-enhanced classrooms could lead to greater teacher innovation and more positive student-teacher interactions between students with LD and science teachers. Teachers may find themselves spending more time encouraging individual students rather than lecturing or providing all the information themselves. The role of the teacher may change from provider of all information to that of an “idea coach” (Songer, 1989, p. 38). Teacher education programs must provide teacher candidates with experiences in teaching science to students with LD by using technology (Egelston-Dodd, 1995).

If science education is for all students, then it is necessary to devise strategies for involving students with LD in science. As discussed in this paper, computer technology provides a powerful tool for getting students with LD actively engaged in learning science. Technology can be used to engage students with learning disabilities in meaningful learning instead of rote practice with discreet scientific concepts. Technologies provide students with mechanisms for accessing data and understanding complex problems, or with opportunities for dialogue and discussion. Once adept at using technology, students have quick access to multiple resources and tools for combining those resources. They can spend less time looking for answers and information, and more time analyzing, reflecting and developing an understanding.

There is a lack of attention in the research, development and implementation of technology to teaching science to students with LD (Egelston-Dodd, 1995). Science educators, special educators and technology educators should make collaborative efforts to develop innovative computer technology tools for making science both cognitively and affec-
tively appealing to students with LD. More research and development efforts are needed to accomplish this task with a genuine concern for making science instruction available to students with LD.

REFERENCES


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