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Featured in this issue:

Color Blindness and Dyslexia

Researching Deaf Scientists

A Field-tested Guide for Science Teachers

Facilitated Communication

Overview of Science and Math Curricula

Editor: John Stiles, The University of Northern Iowa

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CALL FOR MANUSCRIPTS AND REVIEWS

JSPD is published annually and is dedicated to addressing science issues for persons with disabilities, especially those in educational settings.

MANUSCRIPT GUIDELINES

Unsolicited manuscripts are welcomed. You are encouraged to share views of the status of science for persons with disabilities, effective teaching practices, curricula and exemplary work samples that are student produced. Use APA style, double space with wide margins and submit two copies of the manuscript (if printed). Contributors may also send manuscripts on floppy disk. Please use either Microsoft Word (Macintosh) (preferred) or WordPerfect 5.1 (IBM).

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A one paragraph abstract.

BOOK REVIEWS ARE ALSO WELCOMED.

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Journal of Science for Persons with Disabilities

JOURNAL OF
The Science Association for Persons with Disabilities

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Message from the President

Janet Mansfield Davies

Colorado Christian University
Lakewood, Colorado

The Science Association for Persons with Disabilities (SAPD) is an organization composed of teachers, parents, college professors, students and scientists who are concerned with making science courses, content and career opportunities available to persons with disabilities. The National Science Teachers Association (NSTA) is our umbrella organization and supports and encourages our efforts to make information available to as wide an audience as possible. Our membership comes from many countries around the world.

We publish a yearly journal, biennial newsletter, and a current bibliography of articles on science for persons with disabilities from 1924 to the present. These publications are made available to our membership. We would like for all teachers who have had or will have a student with a disability to become members of our organization. Many special education teachers also teach science curriculum. Won't you please join us and help spread the news that science knowledge and opportunities are important for everyone? And tell a colleague or friend! Thank you. Membership information is furnished below.

To become a member of the Science Association for Persons with Disabilities, send \$10 (US\$16 for overseas members; make check payable to SAPD) to:

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Editor's Comment

John R. Stiles

The University of Northern Iowa
Cedar Falls, Iowa

It is with great pleasure that I take over the reins as editor of the *Journal of Science for Persons with Disabilities*. In succeeding Greg Stefanich, I realize that there are large shoes to fill, indeed, as Greg's commitment to the Science Association for Persons with Disabilities can never be overstated. The journal's first year was a fine testimonial to Greg and his contributions to education and the disabled, and I hope that I will be able to continue building upon the journal's strong foundation.

The response to SAPD's call for manuscripts has been gratifying. A great number of dedicated people are making strong commitments in the classroom, in the community, at home, in government and in the private sector to make science accessible for all persons. I am receiving manuscripts which indicate the innovations and commitments necessary to achieve this very important goal across the country are being implemented in a variety of ways.

In this issue, **Judith Bazler** discusses one of the lesser known, or at least lesser acknowledged disabilities, color blindness, and its implications in science. Also, Bazler presents some valuable information about dyslexia, particularly its effects on students in science classes. **Harry Lang** charts his trials and triumphs in his search for a compilation of biographies of deaf scientists, an impressive effort considering the lack of historical information. **Janet Davies** discusses an exciting breakthrough in technology—facilitated communication—for persons previously unable to express their thoughts to others. While some

controversy over FC has erupted lately, Davies has written a balanced account of how FC revolutionized one student's life using this technology. **Robert Weisgerber** describes a new publication targeting teachers of disabled students, and how this resource can assist in providing a barrier-free classroom. **Ed Keller, Jr., Rebecca Keefer** and **E. C. Keller, III** offer a comprehensive bibliography of published works about students with disabilities in a historical context. This valuable research will be of interest to those who wish to chronicle accessibility in the science classroom.

This issue is being printed in Helvetica 12 point font so that it may be easier for visually impaired persons to read. We would appreciate hearing from those who may have comments on its effectiveness. Our thanks to Jim Gallagher of Philadelphia for his suggestion.

It is the hope of SAPD that information relating to disabled science students can continue to be disseminated in such vehicles as this journal so that the awareness of barriers that exist and strategies to remove them may be made known to an ever increasing audience. Please share this edition with a friend or colleague, and encourage them to join SAPD.

Please let us hear from you. Your reactions to the journal and thoughts about its articles are important!

Color Blindness and Dyslexia in the Science Classroom

Judith A. Bazler

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This paper explores the realm of science education for students with color blindness, color deficiency, and/or dyslexia. Understanding these disabilities and adjusting teaching practices and curriculum to accommodate the needs of these students is of particular importance when teaching science.

Following an overview of these disabilities, methods for identifying students with these disorders will be discussed as well as the strategies students employ to camouflage them.

Research for this paper included interviews with preservice and practicing teachers who have these disabilities. Many of the suggestions for helping to spot students with disabilities as well as the methods to teach more effectively are based on input from these teachers. A brief discussion of the issues facing teachers with disabilities, including whether they should reveal their disabilities, concludes this paper.

A variety of instructional techniques (e.g., hands-on, cooperative, interdisciplinary and multisensory) can be incorporated into science instruction to provide support and encouragement for students with disabilities. By providing more opportunities to involve these students in science education, we can ensure that they will develop an interest in science, increase their science literacy and ultimately pursue successful careers in science.

Understanding Color Blindness and Color Deficiency

Color blindness is the inability to distinguish one or more of the primary light colors red, green and blue. Color blindness, which affects about ten to twenty times as many males as females, is a sex-linked recessive characteristic which tends to skip generations. In some cases, it is acquired as a result of diseases that affect the central retina, the optic track, or the cortex.

Cones, or visual cells, exist on the light-sensitive layers of tissue of the retina and assist in color perception. One type absorbs light best in wavelengths of blue-violet and another in the wavelengths of green. The third type is most sensitive to red. The wavelength discrimination apparatus of students with color blindness is not as good as that of the majority of students, thus they see many colors as identical that students without the disorder would see as different.

Blindness to red is called *protanopia*; to green, *deutanopia*; to blue, *tritanopia*; and to all colors, *achromatosis*. Students with red-blindness are ordinarily unable to distinguish between red and green, while children with blue-blindness cannot distinguish between blue and yellow. Those with green-blindness are unable to see the green part of the spectrum.

Children with color blindness are rarely aware of their disability until special matching

tests are used that indicate they are unable to distinguish between hues in one or another part of the visual spectrum. Even when identified, the social-emotional and cognitive correlates of color deficiency in these children are contradictory (Wilkinson, 1990). Although Knowlton and Woo (1989) and Dannemaier (1972) found that students with color deficiencies made more errors on a visual matching test and got lower grades in high school introductory biology courses, Lampe, Doster and Beal (1974) and data collected by Shearron (1964) reveal that children with color deficiencies do not differ from children without color deficiencies in areas of intellect and achievement.

Interestingly, research indicates that the incidence of color-blindness is much higher among children with mental retardation. Opposed to the lower occurrence in the general population, one in every five educable retarded children is color blind. Also, the male-female ratio of color blindness is nearly equal among children with mental retardation (Sewell, 1983).

About 1% of males are dichromats; they can mix all of the colors of the spectrum, as they see them, with only two primaries instead of three. Thus, students with protanopia (red blind) require only blue and green to make matches; since for the noncolor deficient (trichromatic) students the various reds, oranges, yellows, and many greens are the result of mixing red and green, students with protanopia match all of these with a green. In other words, they are unable to distinguish all the hues from each other on the basis of their color; if they distinguish them at all, it is because of their different luminosity (brightness).

Students with protanopia match white with a mixture of blue and green and are, in fact, unable to distinguish between white and bluish-green. Children with deuteranopia (green blind) match all colors with a mixture of red and blue; thus, their white is a mixture of red and blue that appears purple to children

with normal vision.

Children with deuteranopia also are unable to discriminate reds, oranges, yellows, and many greens, so that both types of dichromat described above are classed as red-green-blind. For students with protanopia, however, the spectrum is more limited because they are unable to appreciate red. Students with tritanopia (blue blind) are rare, constituting only one in 13,000-65,000 of the population. Because they are blue blind, their color discrimination is best in the region of red to green, unlike students with protanopia and deuteranopia.

Recognizing Students with Color Blindness and Color Deficiency

Because so much science instruction is color-dependent, students with color blindness will exhibit a broad range of responses to such activities, from loss of interest (e.g. day-dreaming) to complete withdrawal and nonparticipation. Students with color blindness also may become difficult to manage as a result (Olsen and Harris, 1988).

Many adults with color blindness recall feeling as though no one was paying attention to them in class. They also report having suffered from teasing and ridicule. For these reasons, negative social interactions between students should be attended to as soon as they are noticed, and teachers must be especially careful to recognize the achievements of all students. Such acknowledgements will not only bolster students' self-esteem, but also will convey to students (including those with disabilities) the message that they belong in the class and their contributions are worthwhile.

If a teacher suspects that a student has a color deficiency, administering the Ishihara or American Optical Tests for early diagnosis is indicated. This would lessen the negative learning experiences of students with color deficiencies. A newer test, found to be more reliable for preschool screening is the Pease-

Allen Color test (PACT) (Lewis, Reitzammer and Amos, 1990).

Students with color deficiencies can become adept at hiding their problems. They learn to watch their classmates and copy their behaviors and responses. They successfully avoid situations involving color (Olsen and Harris, 1988). At other times, they may actually be scribbling or doodling to give the appearance of taking notes.

Adapting Science Instruction for Students with Color Deficiencies

One of the most effective ways to help students with color blindness is to utilize cooperative learning strategies, particularly when performing color-based activities. Assistance from other students in the group or team can explain what is happening and identify colors for them as they proceed through hands-on experiments and other classroom activities.

Similarly, taking the time to explain and discuss the outcome of a verification type experiment will greatly benefit students with color deficiencies. Involving students in the design of experiments and projects is also helpful. If they know what is ahead, they may have a better sense of how and when to participate effectively. Teaching through problem-solving and inquiry that involves the application of scientific methodology and the generalization of science concepts is recommended (Weisgerber, 1993). This will help students form concepts about science that can be applied to the rest of their lives.

Employing senses other than sight when performing some of the most basic science activities can help children feel more involved and experience some of the hands-on satisfaction that students without color blindness do. For example, teaching a unit on acid-base, traditionally performed utilizing student observations of litmus paper, could also incorporate smell and taste by having students "experiment" with lemon juice. Using a pH meter also helps alleviate color depen-

dency. When performing classification tasks, teachers should emphasize other aspects of objects besides their color: pay attention to size, shape, texture and so on. Multisensory classroom, laboratory and outdoor experiences actually prove effective for *all* students.

Adapting teaching materials to accommodate the color vision defects of each student may be accomplished, quite simply, in a number of ways. Since some students with color blindness are able to perceive certain hues and colors when they are against a white or uncluttered background, a degree of success is ensured when teachers prepare accordingly and stay with basic colors (e.g., red, blue, green, yellow, orange, purple, black, brown). Also, when designing lessons that revolve around color, be sure to use bright, nonpastel colors that are extreme opposites. Handouts in black and white ensure success for the student with color blindness or color deficiency. Black letters on a yellow background and white letters on black afford optimal legibility for the student with color blindness (Lewis, Reitzammer and Amos, 1990; Sewell, 1983).

Use of acetate sheets also helps students utilize textbooks and worksheets with color print. Green acetate laid over pinks and reds and red acetate over blues and greens will increase the contrast and make it easier for students with color deficiency to see pastel printed words.

All colored objects related to a lesson or experiment should be labeled. For example, color-coded solutions used for an experiment involving several concentrations of salt water should be clearly marked (e.g., "Blue: 10% salt," "Green: 15% salt," etc.).

Understanding Dyslexia

Dyslexia is an inability or pronounced difficulty in learning to read or spell, despite otherwise normal intellectual functions. The cause of the disorder is unknown and even its diagnosis is a difficult task; dyslexia is usually

diagnosed in children or adults who have reading difficulties for which there is no apparent explanation. Recent research points to anomalies in the respective functioning of the left and right hemispheres of the brain as possibly being the cause of the disorder, but a conclusive explanation has yet to be found.

A chronic neurological disorder is responsible for inhibiting a student's ability to recognize and process graphic symbols, particularly those pertaining to language. Chief symptoms include: (a) extremely poor reading skills due to no apparent cause, (b) a tendency to read and write words and letters in reversed sequences (identified by distinctive transpositions and other forms of misspelling), (c) similar reversals of words and letters in the person's speech, and (d) illegible handwriting.

Dyslexia is found three times more often in boys than in girls and usually becomes evident in the early school years. The disorder tends to run in families. Only a minority of students with dyslexia remain non-readers into adulthood, but many continue to read and spell poorly throughout their lifetimes. Children with dyslexia frequently perform above average on nonverbal tests of intelligence, however, and can be treated by a sustained course of proper instruction in reading.

Recognizing and Teaching Students with Dyslexia

Since students' written and reading performance is affected by the disorder, their work often belies their status. Thus, increased participation and attentiveness during classroom discussions, of a significantly better quality than homework and tests, is the salient indicator of the student with dyslexia.

As efforts to reform science education continue to emphasize the inquiry process and development of problem solving skills, students with dyslexia will gradually become more equal partners with their nondisabled peers in the classroom. Less reliance on

textbooks, along with encouraging students to approach problems, will help these students succeed in science.

Teachers with Disabilities

If color blindness and dyslexia exist in significant numbers in the general population, then we can assume that a number of teachers have these disabilities. Whether or not they choose to be open about their status affects their success in the classroom. Failure to do so also masks the need for developing materials that could help them to be more effective. Moreover, these disabilities affect the way a teacher approaches all disciplines, including science.

Just as color-coded textbooks can hinder the progress of a student with color blindness, so too will they frustrate the efforts of a teacher with color blindness to assess the accuracy of their students' work. Color-based activities that teach patterns, logic, classification and identification will continue to be problematic for teachers with color defects until alternative strategies are developed, including new textbooks.

Fortunately, teachers with dyslexia have a number of alternatives available thanks to existing technology. Programs that complete spelling checks are an invaluable tool for them. Since teachers with dyslexia do not perform well writing spontaneously on the board, lectures can be presented with the use of overhead transparencies or LCD display panels in conjunction with a computer and overhead projector. To aid dyslexic teachers in writing comments and running spell checks, students should do homework on a word processor when possible.

Teachers with less than obvious disabilities must decide whether to make their disabilities known to their administrators and students. One preservice teacher was open about his dyslexia and the district hired him because he could be a role model for students with dyslexia. By informing their students

about their disabilities, teachers not only educate them about how their lives are affected, but they also may help some students realize that they have a similar disability. Furthermore, students are able to take on a new role—teacher aide—helping their teacher to complete lab activities and other hands-on experiences.

Conclusion

Much can be done to accommodate the needs of students and teachers with color blindness, dyslexia and a variety of other disabilities. In many cases screening tests help to clearly identify the students with the disabilities. Afterwards, however, teachers must remain attuned to the needs of their students and modify instructional techniques and materials accordingly, particularly in the science curriculum.

Teachers' increased sensitivity and a willingness to adapt to the needs of students with disabilities will go a long way toward ensuring that they will become science literate and consider pursuing careers in science.

Teachers, rather than keeping their disabilities from students, should involve their students in helping to complete labs and hands-on activities. Not only will these experiences help students become more empathetic toward people with disabilities, they also will provide a role model for students with similar disabilities.

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The Role of Historical Research in the Science Curriculum for Students with Disabilities

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Over the past fifteen years, there have been numerous calls for increased use of "role models" in the science classroom, particularly for students often considered marginalized such as women, African-Americans, Hispanics, Native Americans and students with disabilities. The belief that success is associated with positive self-esteem may be further validated through historical research, such as the recently completed analysis of the contributions of deaf women and men in the history of science (Lang, 1994). In *Silence of the Spheres: The Deaf Experience in the History of Science*, the reader finds a wealth of qualitative data supporting the need for introducing young students with disabilities to both historical and contemporary role models. Yet, for the most part, this is simply not being done in our schools today.

Resource Development on Contemporaries

A commendable effort has been made to develop resources pertaining to contemporary scientists with disabilities. The American Association for the Advancement of Science (AAAS), for example, has updated and reprinted several times its valuable *Resource Directory of Scientists and Engineers with Disabilities* (Stern, Lifton and Malcom, 1987), which contains the names of hundreds of individuals willing to serve as role models in a

variety of contexts. Printed biographical materials, such as *Able Scientists—Disabled Persons: Careers in Science* (Stearner, 1984) and the Clarke School for the Deaf science curriculum with its twenty-five biographical sketches of deaf scientists, also attempt to address the major issue identified by the National Science Foundation Task Force on Persons with Disabilities, which is the "virtual invisibility of role models in science, science education, and engineering for children with disabilities" (NSF, 1990). In addition, the jointly sponsored efforts by the AAAS and the Xerox Corporation (AAAS, 1978) to support Robert Menchel, a deaf physicist, in his travels around the country to meet with thousands of students, parents, teachers and counselors, provided evidence that such opportunities can have positive effects on the self-esteem and motivation of young students.

In one research study by Lang and Propp (1982), however, it was found that only one-third of nearly 500 science teachers of deaf students in 326 programs introduced information about deaf scientists in their classes, and only 9.4% of all the respondents invited living deaf role models into their classrooms. More recent data are not available, but it is unlikely that the percentages have improved dramatically, since no literature has been made available on this topic until this year.

The Value of Historical Research: An Author's Perspective

When I embarked on my search for finding the "Deaf Experience" in the history of science, I had not located previously published information on this topic and had no idea of what I might discover. To some, my research methodology might seem idiosyncratic and laborious. I visited library after library, in the United States, Canada and in Europe. I walked along the stacks and selected book after book and simply speedread the pages, searching for the term "deaf," or its equivalent in other languages, such as "taub" (German); "sourd" (French); and "dov" (Swedish) with many hours going by without any findings. Once I found mention of deafness, I followed up with archival research, writing letters to surviving family members, examining obituaries, personal diaries and journals, and any other reference that might provide more detail on the individual's age of onset of deafness, magnitude of hearing loss, and the challenges and accomplishments of the person. Hundreds of letters were written and received in the process and the results were fulfilling.

One by one, I found Nobel laureates, discoverers of chemical elements and scientific principles, and founders of scientific societies, some honored with such titles as "Dean of Women Astronomers," "Dean of American Horticulture," "Founder of North American Paleobotany," and "Father of Astronautics." Each of these scientists has a story to tell about overcoming attitude and communication barriers in pursuit of science and detailed biographies of many of these individuals will be published next year in *Deaf Persons in the Arts and Sciences: A Biographical Dictionary* (Lang and Meath-Lang, in press). For the science teacher of deaf and hard-of-hearing students, there will be several comprehensive references.

The Value of Continuing Research

In the process of conducting this research, I realized how extensive the invisibility has been historically with regard to the accomplishments of scientists with disabilities. Not only did I find numerous reports of scientists with other disabilities, easily enough for another book on the topic, but I am convinced that there is a plethora of information remaining to be discovered. The value in discovering these women and men, and in writing about them, is that such efforts will certainly help to break down attitude barriers. The number of deaf medical doctors and dentists I discovered in history, for example, would likely assist a deaf student who encounters resistance in applying for medical school. The fact that both congenitally and adventitiously deaf medical doctors have succeeded in a variety of specializations over the years would be important to a lawyer who may be asked to take the case. Knowing that a profoundly deaf medical doctor received the Nobel prize for discovering the source of typhus fever, thus saving thousands of lives, is certainly an additional argument for opening the doors of medical schools to the deaf or hard-of-hearing student. Yet, even after two decades of teaching science myself, I had never heard of Charles Nicolle until a deaf philatelist learned of my research and sent me Nicolle's name.

Over the past few years, I have been presenting a slide show about the Deaf Experience in the history of science to both adult and student audiences, and I have not been disappointed at the surprise and enthusiasm that results when the information is shared. After years of studying the lives of these deaf scientists, they had become like brothers and sisters to me. Last year, I borrowed a book from the library with a list of the craters on the moon, and was thrilled to find that six craters were named in honor of deaf and hard-of-hearing men and women. Now, deaf science students can turn their telescopes to the heav-

ens and know that thousands of binary star systems, comets, novae and other celestial objects have been discovered by deaf people in history. As the Voyager spacecraft continues to travel outward, our students need to know that on board is a phonograph invented by Edison, who was very deaf for most of his life. The last piece of music played on Voyager's record was composed by Beethoven after he was totally deaf. And the spacecraft was blasted into space, escaping Earth's gravitational pull, with a velocity calculated by the "Tsiolkovsky formula," named in honor of a deaf Russian rocket pioneer.

Instructional Strategies and Materials

Silence of the Spheres: The Deaf Experience in the History of Science was written for teachers to provide a scholarly rationale for their efforts to develop multicultural materials and strategies in the science curriculum. Numerous suggestions have been sent to me for such strategies, and now, I believe, this is one challenge we must undertake in science education for deaf students over the next few years—to help build self-esteem by incorporating this information into lesson plans. Over the next few years, I hope to establish a network of science teachers willing to share successful strategies with one another, and to participate in research and development projects to examine the efficacy of these and other efforts. Indeed, this is one of the recommendations I made at the 1993 working conference for Science Education for Students with Disabilities, funded by the NSF and coordinated by Greg Stefanich at The University of Northern Iowa (Lang, 1994). The science teachers in this network will experiment with gaming strategies, mediated materials, "Deaf Scientists Cards," crossword puzzles, infusing information about deaf scientists into lesson plans and other activities. The broad goals will be to increase science as a career choice among the nation's deaf students, create a means of communication, and de-

velop a passion for knowledge.

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A Field-tested Guide for Science Teachers of Students with Disabilities

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The second edition of *Science Success for Students with Disabilities* is currently in press at Addison Wesley in Menlo Park, California and is expected to be available this year. The first edition, which was developed in collaboration with teachers in the field, was used in an extensive national field test and distributed to attendees at the invitational conference of the Science Association for Persons with Disabilities at the 1993 National Science Teachers Association convention.

Workshops and seminars were held at eleven sites nationwide, and included both inservice (multi-school district) and preservice (university) sessions. The feedback from these workshops, attended by K-12 teachers and administrators, was overwhelmingly positive, and participants suggested further improvements. These suggestions have been incorporated in the revised second edition of the guide. The guide was developed, field tested, and revised by staff at the American Institutes for Research with grant support from the National Science Foundation (DUE-9154031).

Addressing Issues of Disabled Students in the Classroom

Following are some of the questions and concerns that science teachers and administrators may express when a student with a disability is in their regular class or program.

Each includes a description of how the guide addresses the issue.

* *Does a student with a disability really belong in my science class?*

The guide points out that all students can benefit from science instruction; that "good science" involves hands-on learning, cooperative learning and interdisciplinary learning which are beneficial to students with disabilities; that special education staff will cooperate; that barrier reduction involves both physical and attitudinal barriers; and that accommodations can and must be made on behalf of the student with a disability.

* *I don't know anything about (disability condition)—how can I find out what I need to know?*

Disability-specific guidelines are provided for teachers of students who are blind, have low vision, are deaf or hard of hearing, have physical disabilities, a learning disability, speech disorder, or an emotional disorder.

* *What kinds of changes do I have to make in my instructional style?*

Emphasis is given to developing positive attitudes and assessing the student's interpersonal skill and self-esteem; helping the student identify and deal with personal barriers; and managing the instructional environment by (a) advance planning, (b) using creative solutions to learning tasks, (c) applying science processes to teach "good science," and (d) using flexible, fair assessment

procedures to evaluate student progress.

** What about the rest of the class—how can I focus on this student and the other students at the same time and how will the others interact with this student?*

Numerous specific strategies are offered for reducing instructional barriers for students with the previously named disabilities. The suggested strategies are grouped according to (a) teacher-centered instruction, (b) student-centered activities, and (c) partner-centered and team activities.

** Am I expected to involve the child with a disability in most lab activities?*

Yes. Hands-on, direct experience-type activities are included in the strategies mentioned above.

** What about involving the student in out-of-school science activities?*

A variety of ideas are provided for involving students with disabilities in out-of-school activities, and the need for planning and teamwork is emphasized in the barrier reduction section of the guide.

** What resources can I draw upon to help meet the student's needs?*

In addition to the human resources within the school district (e.g., special education staff and technology specialists), an annotated list of external resources (e.g., disability-focused organizations and manufacturers of special equipment and software) is provided in the guide.

** How can I get training on an inservice basis?*

Three appendices provide all that is needed to organize local workshops. Sample case vignettes are included so that workshop participants can work collaboratively on "typical problems" they might encounter for each type of disability.

Reducing Teacher Anxiety

Finally, the guide is meant to reduce anxiety on the part of teachers by giving them needed information, by suggesting instructional strategies that do work, and pointing out

resources that can be tapped. In addition, the guide provides suggestions for workshops and, importantly, by directly involving the disabled student in the planning and learning process. One teacher had this comment about the guide:

"I have an arsenal of strategies to try. This makes me feel much more confident in instructing these students. This makes me an 'I can' teacher for an 'I can' student."

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Facilitated Communication in Science Class: A Move Toward Inclusion

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Facilitated Communication (FC) is a term used to describe a process whereby a student with a language and/or language-motor disability is physically assisted (or facilitated) by another person in using a technological device to communicate. The device may, for example, be a typewriter, computer, communication board, or a portable modified typewriter. Some registered names for small, portable typewriters are Canon Communicator, Franklin Language Master and Crestalk (Crestwood, 1994).

Pioneering Facilitated Communication

In the late 1980s, Rosemary Crossley reported that many students challenged with autism, mental retardation or cerebral palsy were able to communicate, via FC, in words and sentences. Crossley pioneered the method with her students in Australia (Crossley, 1990). Douglas Biklen, a special education professor from Syracuse University, heard about the method, traveled to Australia to observe the process, and brought the technique back to the United States (Biklen, 1990; Biklen and Schubert, 1991). Since that time, Biklen has traveled across the U.S. giving training to parents and educators in how to facilitate communication with their own children and students.

To say that a breakthrough took place is quite an understatement! An "FC explo-

sion" occurred almost overnight. Many parents and teachers were startled to discover that students who were once thought not able to communicate and incapable of intellectual thought were very capable of self expression. Parents and teachers were suddenly confronted with students who were not only communicating with correct words and sentences, but many were found to possess highly intellectual thought processes. It just might be that FC will ultimately bring about a paradigm shift in how professionals will characterize students with autism (Shulinsn, 1994).

In order to facilitate communication, a facilitator (parent, teacher, aide, peer, friend, etc.) generally sits on the right side of the person with a disability (if that person is right-handed, left side if the person is left-handed) and supports the person's hand to steady it while the person touches keys on one of the above-mentioned technological devices. The facilitator's hand is palm up under the student's hand and holds the hand in such a way so that the student will use his/her pointing finger to strike the keys. After the key is struck, the facilitator puts upward pressure on the student's hand to remove it a few inches from the keyboard. This kind of assistance may be all that is needed for some non-verbal students to communicate. Other students may need only a light touch on the arm or shoulder for assistance.

A Success Story

Let me share Blake's story with you. Blake is a secondary-aged student living with his parents in Texas. For most of his life he attended a segregated school for special education students who were severely and profoundly disabled. Blake is non-verbal and has autism. Because of an inability to communicate, Blake had severe behavior problems. Blake's parents became aware of Facilitated Communication, took the training course, and began working with Blake at home. Much to their surprise, Blake began to "talk" by pointing to letters on the typewriter, computer and laminated alphabet board. The parents did not know that Blake knew how to read. When they asked him how he had learned to read, he typed out words indicating that he learned to read a long time ago from watching commercials and "Sesame Street" on TV.

Blake told his parents that he wanted to study biology, so they inquired about sending him to their local high school. Although the teachers and school personnel had not heard about FC, they were willing to allow Blake's mother to attend school with him and be his facilitator in biology class. Blake not only understood the science content, he loved it!

Shortly thereafter, the school provided Blake with a teacher's aide, which allowed his mother to return to her office. The science teacher and biology classmates learned to facilitate with Blake. Other students, ones who did not know Blake but were interested in the communication board hanging around his neck, began to ask questions of him and facilitate with him in the hallways, in physical education class, or in the cafeteria (Sposato, 1993). Blake was socializing in an appropriate manner! He was also fully included in the regular biology classroom, for lecture, coursework and group activities.

Helping Other Special Students

How many more Blakes are out there

who are currently segregated in special classrooms when they could be integrated in regular classrooms? Are there students who are non-verbal and who would like to participate in a "regular" science class, but are unable to tell anyone? Would it be possible for students who are challenged mentally, those with cerebral palsy, and those with autism to begin participating with typical peers in a regular classroom setting? Would Facilitated Communication make it possible for some students with severe disabilities to make their own choices about their future careers? This author believes the answers to the above questions are YES!

Many special students CAN be successful in learning science content if given the opportunity (Davies and Ball, 1978; Davies, 1993). Facilitated Communication may be one technique used to assist those students who may need special help in the classroom. It's worth a try!

There are some strong precautions to note, however, as reported in the current literature. One needs to be sure that it is the student who is doing the communicating, and not the facilitator (Bligh, 1993; Eberlin et al., 1993; Hudson et al., 1993; Moore, Donovan and Hudson, 1993; Rimland, 1993; Wysolmierski, 1994). If a student wishes not to be touched, some alternatives to touching the hand could be used, such as (a) the facilitator hooking his/her finger in the cuff of a long-sleeved shirt worn by the student and gently exerting the necessary pressure to keep the student from perseverating on a key; (b) using a 12-18 inch dowel rod with the student holding onto one end of it while the facilitator holds onto the other end; (c) putting a terry cloth pony-tail hair band on the wrist of the student, making it possible for the facilitator to support the hand by holding onto the terry cloth band.

Facilitated Communication is not a cure for a person with a disability. Many students need to learn their alphabet and how to read and spell before they show much progress

with the communication devices. On the other hand, some students may surprise their facilitators with their apparent photographic memories and their ability to glance at a printed page or keyboard and "know" the key positions, even when they are not looking directly at their communication devices. Parents and teachers may be quite surprised, as were Blake's parents, when they find that a student's behavior and apparent intelligence improve when he/she becomes able to communicate with another person.

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A Historical Overview of Literature Concerning Science and Math Curricula for Students with Disabilities

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Educators began modifying and designing curricula for teaching science and math to students with disabilities as early as the 1920's. Although these early efforts were created specifically for students with vision impairments, these works laid the foundation for later educators to include facilitation for students with other disabilities in their curriculum designs.

Some of the terminology used herein may not be current. However, to retain the historical significance of the literature surveyed, terms are used that were current at the time of the respective writings, but may not be appropriate for contemporary correctness. The earliest publication surveyed was by French (1923), which was presented at the 27th biennial convention of The American Association of Instructors of the Blind. The survey continued to include literature published up to 1990, but few recent articles were found.

Historical Overview of the Literature

The Science Activities for the Visually Impaired (SAVI) program is designed for grades 9 through 12. Key concepts in the physical and life sciences are taught using a multi-sensory approach. Students learn to make predictions, carry out experiments, and draw conclusions. "Hands-on" activities are organized into modules and presented in "folio" form. The five modules are: 1) Scientific Reasoning; 2) Structures of Life; 3) Mixtures and Solutions; 4) Communication; and 5) Environments (Laetsch et al., 1979). SAVI is a carefully planned, but flexible, program designed to "neutralize" the students' disabilities in the classroom. The application of SAVI materials does not require specialized equipment (Schnur et al., 1978). Through the use of SAVI, students develop logical thinking skills, improve manipulative skills, and discover ways to apply these skills to everyday

experiences (Malone and DeLucchi, 1979; Malone et al., 1981). SAVI has been evaluated by techniques ranging from unstructured observation to formal testing. This program has demonstrated the value of multi-sensory "hands-on" materials in educating visually impaired individuals (Thier, 1981). Workshops also have been implemented to train teachers in the use of the program.

Science Enrichment for Learners with Physical Handicaps (SELPH) is a project based on SAVI materials (Tunncliffe, 1987). Teachers recognized the potential for SAVI's use with students having other disabilities (Anonymous, 1980c). SELPH, designed for children in grades 4 through 7, employs a multi-sensory approach to teach science to students who have vision, orthopedic, learning, or hearing disabilities, as well as students having multiple disabilities. In addition to the five aforementioned modules of SAVI, there are four others included in SELPH: measurements, magnetism and electricity, kitchen interactions, and environmental energy (James, 1987). Each module contains information about modifications in equipment and procedures appropriate to particular disabilities (Anonymous, 1980c). The applications of SELPH include: 1) the teaching of science concepts, 2) the development of science process skills, 3) the improvement of manipulative skills, 4) the enhancement of language development, and 5) the motivation of learning and integration in the classroom. SAVI and SELPH were developed at the Lawrence Hall of Science, University of California, Berkeley (Anonymous, 1976-79). Full Option Science System (FOSS), a follow-up program to the SAVI/SELPH, is now available (Anonymous, 1992).

Ball (1978, 1979) described the Elementary Science Study (ESS) as a "hands-on," interdisciplinary, science curriculum program, for special education grades 1 through 12. The 28 activities of ESS include such facilitating titles as Mirror Cards, Pattern Blocks, Clay Boats, Mapping, and Earth-

worms. Each activity provides a summary, as well as objectives, methods, and time requirements.

Adapting Science Materials for the Blind (ASMB) is based on the Science Curriculum Improvement Study (SCIS). ASMB enables blind and visually impaired students to participate in SCIS activities (Thier, 1981). SCIS is a laboratory-based program emphasizing student involvement with science materials (Struve et al., 1974b; Struve et al., 1975). The program can be adapted to individual academic abilities and levels of independence (Schatz et al., 1976a). In a survey of 146 teachers who used this adaptation of SCIS, positive comments were expressed about the program; however, feelings of inadequacy by the teachers while teaching students with disabilities were also mentioned (Atwood et al., 1985).

Visually impaired children participating in an ASMB program scored significantly better in content, process, logical thinking, and manipulative skills than visually impaired children who participated in science classes that were not adapted to their disability (Linn, 1972; Long, 1973; Struve et al., 1974a; 1975). Bybee (1972) advocated the ASMB program for the use of students with hearing impairments in need of adapted science materials to learn more effectively because of the nature of their impairment.

Cobel (1977) described a curriculum program in science and mathematics for students with disabilities in mainstreamed classrooms. The curriculum consisted of two sections, each with 36 weeks of activities. Each lesson had a daily objective, a section on teacher preparation, and descriptive pictures. Some of the science activities were: describing colors, size, and shapes of objects; observing changes in matter; friction; and gravity. Some of the math activities involved learning to count, fractions, and the metric system.

Parallel Science Materials (PSM) is a modified and adapted multi-sensory curricu-

lum in the life and earth sciences written at an "easy" reading level for students with disabilities mainstreamed into regular classrooms (Barkey, 1979). PSM consists of fourteen units in life science and six units in earth science, each containing objectives, activities, teacher guidelines, vocabulary, experimental procedures, discussion, and questions. Kaschner (1978) described another multi-sensory earth science program that included soil type identification, stream table erosion, and relief map activities.

Part 2 of "Science for Handicapped Children" for ages 11 through 16 consists of science activities in the following categories: 1) chemicals around the home; 2) electricity; 3) ice and water; 4) forms; 5) candles, light, and hot air; 6) strength of materials; and 7) a collection of several short activities on various science topics (Jones, 1983). All of the materials needed for the experiments are readily available and easy to assemble. Another elementary science program for students with disabilities, developed in Milwaukee and adapted from the Handicapped Project at the Manitoba Science Center, includes subjects ranging from "Air and Water" for grade one to "Heredity" for grade six (Swanigan et al., 1982b).

Earlier general science curricula were reported by Botts (1934), Coville (1932a), Gibson (1932), Hurst (1933), and Myers (1935; 1943). There were other programs related to science curriculum and students with disabilities. Langworthy (1935) detailed an experiment in teaching astronomy to blind students at the Perkins Institute for the Blind. Santoro (1983) described the television series "3-2-1 CONTACT," a closed-captioned in-school science program for hearing impaired students, that provided them with "decoders" in order to take advantage of the captioned series. Three years of free taping rights were given with the program.

Levenson (1984) offered strategies for teaching health education to chronically impaired individuals. Frith (1981) described a

vocational program in horticulture for secondary students with disabilities.

A college level beginning biology class for visually impaired students was described by Cooperman (1980). Topics included chemical bonding, diffusion, osmosis, cell structure, meiosis-mitosis, reproduction, behavior, nutrition and circulation. Non-sighted students evaluated a botany laboratory exercise adapted for visually impaired students (Wright, 1978b). To determine the success of the program, an oral quiz was given to the blind students, while a written test was given to sighted students. The mean and median scores of the blind students were found to be comparable to those of the sighted students. The adaptations, using a multi-sensory audio tutorial approach made use of actual specimens as well as clay models (Wright, 1978a, 1977). Bryan (1932) also described an early program in biology using clay models. Other biology curricula were reported in the literature by Cravats (1972), Billings (1980), and Francouer and Eilam (1975).

Manuals from the Initial Learning in Mainstreaming Project (ILMP) covered several areas of mathematics including: 1) Least Common Denominator; 2) Multiple Multipliers (to 3 digits); 3) Off Base 10, Working with Years, Months, Weeks, and Days; 4) Off base 10, Working with Hours, Minutes, and Seconds; and 5) Long Division to Remainder. The program was developed to teach mathematical concepts to mainstreamed students with disabilities. Each manual included tests, worksheets, and pages that can be made into transparencies for projection (Tipton et al., 1976a; 1976b; 1976c; 1976d; 1977). The ILMP led to the development of another series of three manuals of mathematical concepts for mainstreamed elementary students with disabilities. Subjects covered in the manuals were: 1) Subtraction (Regrouping); 2) The Carrying Process; and 3) Rounding Numbers. These manuals consisted of tests, worksheets, and pages that could be made into transparencies for projection (Kingston,

1976a; 1976b; 1976c).

Some mathematics programs were developed for use in teaching students with disabilities. One program used fruit salad to teach 15 to 20 year old students with multiple disabilities about fractions (Lincoln, 1987). Another program reported by Mosley (1986) called "Count Me In" included twenty-three number games for primary grade children with or without sensory and physical disabilities. One hundred cards were used in numerous ways to teach various mathematical concepts in the program. Cook (1956-57), Cohn and Eulert (1982-83), Cox (1975) and Dodd (1975) discussed other mathematics curricula.

Olsen (1970) reported that students at the Oregon State School for the Deaf viewed a solar eclipse and manipulated equipment to observe sunspots. The experience led to an interest in the effects that sunspots have on the earth.

Other disability-adapted curricula offered such diverse classes as health careers (Beller, 1978); educational experiences at a zoo (Berkovits et al., 1980); ornithology (Daniel, 1954); sex education (Enis and Cataruzolo, 1972; Knappett and Wagner, 1976); fishing (Frith, 1980); dendrology (Heisler, 1944); horticulture (Lee, 1983); gardening (Piltz, 1968); and nature study (Vaughn, 1929-1930).

Loeb (1981) developed several laboratory programs that allowed visually impaired students to handle chemistry materials in a constructive and safe way. Another study described a quantitative chemistry experiment, conductometric titration, adapted for blind students (Hiemenz et al., 1972).

Evaluations of Resources

Several of the references contained evaluations of programs, adaptive materials and modified teaching methods for use in teaching science and engineering to students with disabilities. Articles related to evaluation in mathematics were most common. One

such article described a survey of math teachers and reported that new teaching methods were being evaluated to meet the learning needs of blind students (Lewis, 1970). A study reported by Brothers (1972) used Form X of the SAT (Scholastic Aptitude Test) to determine the achievement level of students who used Braille in arithmetic computation. The results showed that achievement levels of these students in 1970 were below those of 1959.

McCrimmon (1974) wrote of a second study assessing a programmed instructional sequence for the abacus. In a somewhat related project, the soroban (a type of abacus) proved to be a practical and efficient approach for overcoming computational problems encountered by blind students (Nolan and Morris, 1964). Another study (Suppes and Fletcher, 1974) discussed the evaluation of a three year computer-assisted instruction (CAI) network for hearing impaired students conducted by the Institute for Mathematical Studies. The results of this study indicated that students using CAI could make gains in mathematical computation of up to three times greater than those made in regular classroom instruction. In addition, Bornstein (1964) noted an evaluation that relied on pre- and post-tests to assess programmed texts that were being used in high school math classes for deaf students.

Chibrowski (1988) wrote of the development of a text analysis tool that could determine if a textbook contained enough effective teaching strategies for students with disabilities, and Franks (1974) published the assessment of a map reading project for blind students. Two other papers by Franks et al. (1973a; and, 1978) discussed the assessment of the legibility of plastic models that were being used to teach blind students. Both papers revealed that an experimental group of blind students achieved a correct response 95% of the time.

Among the evaluation-related publications were articles concerning evaluative stud-

ies. One such study reported by Mallinson (1967) assessed the feasibility of using programmed learning materials with blind students, while a study reported by Struve et al. (1974b) assessed what effect experiences would have on the manipulative skills of visually impaired children. In addition, Lang (1982) and Hill (1971) published articles on evaluative studies.

Several programs and projects were also evaluated. Searle et al. (1973), Hadary (1978b), Hadary and Cohen (1978a), and Peterson and Sullivan (1982) all published articles concerning the evaluations of several instructional programs for students with disabilities. Berger (1978) reported on the evaluation of a project designed to encourage students with physical disabilities and adults to enter some area of science as a career. Evaluations of the "Science for the Hearing Impaired" project and a project concerned with students with severe disabilities were written by Sunal and Sunal (1981) and Fawber et al. (1978), respectively.

Other evaluation-related articles included: 1) assessments that were used when adding a course in general science at the California School for the Blind (French, 1924); 2) some suggestions for evaluation approaches (Lang et al., 1983); 3) an assessment of comprehension gains in a group of hearing impaired students (Diebold and Waldron, 1988); 4) a paper on teaching chemistry to students with disabilities that contained a section on evaluation (Reese, 1981); 5) an assessment of cognitive and social aspects of a mainstreamed setting for deaf children (Linn et al., 1979); 6) an examination of the effectiveness of Science Curriculum Improvement Study materials for visually impaired children (Long, 1973); and 7) a discussion of an evaluation of a vocational agriculture program for students with disabilities (McCracken et al., 1985).

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