AN EXAMINATION OF TWENTY LITERACY, SCIENCE, AND MATHEMATICS PRACTICES USED TO EDUCATE STUDENTS WHO ARE DEAF OR HARD OF HEARING

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The results of a multistep process to begin identifying best practices in deaf education are presented. To identify current practices, a survey was conducted of the literature, the Web sites of professional organizations, and states' education Web sites, which yielded a number of commonly discussed practices. Ten of the more highly cited practices in literacy instruction and 10 of the more highly cited practices in science and mathematics instruction were identified for additional scrutiny. Hundreds of articles were examined to identify research support for the 20 identified practices. Some practices had adequate research support; others had minimal support. The authors identify each of the 20 practices, describe the practice, present a summary of the literature that was examined, and rate the usefulness of the knowledge base relative to a "best practice" designation.

Federal mandates surrounding the No Child Left Behind Act instruct schools to engage in best practices when instructing all students. This directive was part of the impetus for the development of a grant titled "Join Together" awarded to the Association of College Educators-Deaf/Hard of Hearing (ACE-DHH). Under the auspices of this grant, a team undertook several actions to gather information about practices in deaf education. In the present article we describe the process of identifying the practices, list each of the 20 practices we examined, provide an expanded definition of each practice, and identify some of the literature that may support each practice.

The team, referred to as Topical Team 2.2, engaged in a multistep process to examine deaf education practices. First, it reviewed best-practices Web sites, looked at states' curriculum Web sites, interviewed representatives of state agencies responsible for curriculum and instruction for students who are deaf or hard of hearing, and considered the literature in literacy, science, and mathematics as it related to students who are deaf or hard of hearing, in order to generate possible practices for inclusion in the document. The team generated a list of 10 practices in literacy and 10 practices in science and mathematics that were routinely cited either in the literature or as field-supported practices. The original set of practices was shared with the ACE-DHH community via the organization's listserv as well as the Master Teacher listserv of the Join Together grant, which led to a modification of some of the wording associated with the practices. Upon review of the original practices, the team noted that the practice of reading and writing in the content area was identified under both literacy and the content areas of science and mathematics. This practice was reassigned solely to literacy to avoid redundancy. In addition, reviewers of the original list indicated that the first science/mathematics practice was quite extensive and needed to be considered as two practices. This advice was followed, the result being the list of 20 practices identified in the present article and examined at greater length.

A caveat is warranted at this juncture. Inclusion in the list of practices that resulted from the selection process we have described is not intended to imply that any of the selections are best practices; rather,

they are examined practices. Neither does exclusion from the list imply that other practices are not of equal value. The described practices do not represent an exhaustive list and are not the only practices that are successful with students who are deaf or hard of hearing. In addition, the literature cited in the present article is not intended to be taken as an exhaustive list of the available research studies, but, rather, as some of the highlights of a review of nearly 500 articles.

Literacy Practices

In this section of the present article we list the 10 literacy practices that were researched, provide an expanded definition of each practice, then present the literature in support of the practice.

Literacy Practice 1: Independent Reading

Independent reading entails providing and monitoring level-appropriate reading materials for independent reading activities as well as time set aside for reading.

Description of the Practice

Independent reading involves providing students with sufficient opportunity and time to read on their own. This practice is based on the notion that "nothing succeeds like success." Many programs have been used in schools over the years such as Sustained Silent Reading (SSR) and Drop Everything and Read (DEAR). There is much evidence from regular education that the opportunity to read promotes students' motivation and interest in reading (Yoon, 2002). Fundamental to independent reading is the use of carefully chosen level-appropriate reading materials (Fountas & Pinnell, 1996).

Evidence

Independent reading is both a goal of literacy instruction and an instructional strategy promoted in schools. Dry and Earle (1988) felt that reading is both overtaught and underpracticed. In a descriptive article, they detailed the processes and procedures involved in designing and implementing independent reading programs for children with hearing loss. These included

* giving students time to read books of their own choosing

* allowing students to enjoy good books and stories at many different levels

* observing, commenting on, and enjoying student strategies as students re-read sections or tell others what they are reading

* allowing students time to find their own levels and discard books they become disinterested in while encouraging them to find other books

* having students keep a simple record of reading

* stating broad reading goals openly

Although there is field-based support for this practice (Dry & Earle, 1988; Schleper, 1994), we found a developing knowledge base with no research comparing outcomes for groups of students who were deaf or hard of hearing and who engaged in independent reading with outcomes for groups of students who did not engage in independent reading.

Literacy Practice 2: Use of Technology

Use of technology entails the application of media such as CDs, captioned materials, and interest-based Internet sites that are known to be motivating.

Description of the Practice

Use of technology includes the use of CDs, captioned materials, interestbased Internet sites, and other technology as visual support to information being presented in the classroom. It is considered a best practice when it is used to support the teacher's skilled explanation and discussion of the subject being taught. It is not considered a best practice when used as a primary source of instruction.

Evidence

Few, if any articles, describe the impact of CDs, captioning, and Internet-based instruction. No research-based articles were found on the use of CDs per se as a category of tools, although they continue to be mentioned in the literature under the category of visual materials that are appropriate for "visual people" (Lane, Hoffmeister, & Bahan, 1996, p. 116). Regarding captioned media, there is little available evidence to guide educators regarding the rate at which captions should be presented relative to a student's individual reading rate. Hertzog, Stinson, and Keiffer (1989) found that deaf college students benefited from captioning presented at the eighth-grade level. While the use of captions was motivating to some students with hearing loss and facilitated vocabulary retention (Koskinen, Wilson, & Jensema, 1986), other researchers found that captions tended to be presented too fast for most deaf readers to follow (Shroyer & Birch, 1980). There is a growing body of practice-based evidence suggesting that specific Web-based instructional programs such as SOAR-High may provide necessary visual support (Barman & Stockton, 2002). These important lines of study indicate that the research base concerning the instructional use of technology is developing. Successes with deaf adults need to be documented in the developing reader.

Literacy Practice 3: Phonemic Awareness and Phonics

Phonemic awareness and phonics are taught either through structured, auditorially based programs with appropriate modifications for oral students or through the use of specialized materials and techniques that provide visual support (e.g., Lindamood-Bell, Visual Phonics, Cued Speech, teacher-developed visual materials) to students who sign or need additional visual support.

Description of the Practice

Phonemic awareness, according to the National Reading Panel (2000), involves six skills:

* phoneme isolation, which requires recognizing individual sounds in words, for example, "Tell me the first sound inpaste" (/p/)

* phoneme identity, which requires recognizing the common sound in different words, for example, "Tell me the sound that is the same in bike, boy, and belt" (/b/)

* phoneme categorization, which requires recognizing the word with the odd sound in a sequence of three or four words, for example, "Which word does not belong? bus, bun, rug' (rug)

* phoneme blending, which requires listening to a sequence of separately spoken sounds and combining them to form a recognizable word, for example, "What word is /s/ /k/ /u/ /l/?" (school)

* phoneme segmentation, which requires breaking a word into its sounds by tapping out or counting the sounds or by pronouncing and positioning a marker for each sound, for example, "How many phonemes are there in ship?" (three: /s/ /I/ /p/)

* phoneme deletion, which requires recognizing what word remains when a specified phoneme is removed, for example, "What is smile without the /s/?" (mile)

(The preceding list can be found at National Institute for Literacy, Assessment Strategies and Reading Profiles, http://www.nifl.gov/readingprofiles/ MC_Phonemics.htm.)

According to the National Reading Panel (2000), phonics instruction is a way of teaching reading that stresses the acquisition of letter-sound correspondences and their use in reading and spelling. The primary focus of phonics instruction is on helping beginning readers understand how letters are linked to sounds (phonemes) to form letter/sound correspondences, and to help them learn how to apply this knowledge in their reading.

Evidence

The evidence for the support of phonics and phonemic awareness provides a mixed viewpoint. Some authors have found that phonemic awareness does not relate to reading ability in students who are deaf or hard of hearing (Izzo, 2002), while others have found that certain aspects of it do (Luetke-Stahlman & Nielsen, 2003). While deafness per se does not preclude phonemic awareness ability (Miller, 1997), some students who are deaf or hard of hearing tend to develop it more readily than others, and phonemic awareness skills correlate with overall reading ability (Dyer, MacSweeney, Szczerbinski, Green, & Campbell, 2003). Regarding phonics, or orthographic development, Irezek and Malmgren (2005) provide evidence that students who are deaf or hard of hearing can learn phonics skills when they are presented via a combination of auditory and visual strategies.

Apparently, traditional phonemic awareness and phonics instruction work for some students and not for others. Some students are able to develop phonemic awareness and phonics skills through audition alone. Some need the support of visual information. Still others are not successful with phonemic awareness or phonics at all. Perhaps a key to this dichotomy is that deaf educators tend not to address the phonological components of reading (Leybaert, 1993). This reticence may lead to inadequate instruction in these skills. Another factor may be the lack of an adequate means of determining which students would benefit from auditory support versus visual support, when the range of hearing loss and

varieties of learning styles of deaf and hard of hearing students are taken into consideration. Given the generally poor reading outcomes among students who are deaf or hard of hearing, educators cannot afford to ignore any avenue that may provide students with access to literacy. The research base in this area is developing.

Literacy Practice 4: Metacognitive Reading Strategies

Metacognitive reading strategies involve teaching skills such as re-reading, looking at pictures, predicting, and visualizing before, during, and after reading through guided reading activities to promote text comprehension.

Description of the Practice

Reading strategies are an important set of tools that help promote text comprehension. Reading strategies are based on metacognitive ability and provide students with a series of steps by which they can construct meaning from print. Reading strategies are often categorized into actions prior to reading, during reading, and after reading, and include-but are not limited to-activating prior knowledge, clarifying, predicting, visualizing, restating, re-reading, using context dues or key words, skimming or scanning, and summarizing. These strategies are taught and then reinforced through guided reading.

Evidence

Brown and Brewer (1996) compared hearing and deaf readers matched for reading level and found that comprehension increased when students drew inferences while reading. They found differences between skilled and nonskilled readers rather than between deaf and hearing readers, which indicated that deafness per se did not prevent the development of word decoding or text comprehension of both factual and inferential material in the population they studied. Strassman (1997) reviewed the literature on metacognition and reading and found very few resources; however, she did note that metacognitive strategies are associated with positive literacy outcomes but that teachers as a whole may not be using these strategies sufficiently. Schirmer, Bailey, and Schirmer-Lockman (2004) found that deaf students benefit from reading strategies but that their repertoire of strategies is limited. As with other reading practices, educators cannot afford to ignore any practice that works. The research base for the practice of teaching reading strategies is sufficient to consider that it may be a best practice.

Literacy Practice 5: Writing to Promote Reading

Writing to promote reading involves the promotion of reading skill development through written language applications such as dialogue journals, research reading and writing, language experience stories, writing to read, and other language-based writing programs.

Description of the Practice

Written-language applications may be used as means to assist students in their development of literacy skills. Dialogue journals are probably the best researched of these tools. The Laurent Clerc National Deaf Education Center (2004) has identified research reading and writing as a tool with which students investigate nonfiction topics and report in writing to demonstrate comprehension. The language

experience approach (LEA) involves the development of stories to reinforce reading and writing by using a learner's personal experiences and natural language. Writing to read is an informal writing strategy in which students record personal predictions, observations, and reflections on content-area information. This is very similar to writing in the content areas, also called writing to learn, except that the intended outcome is improved literacy rather than improved comprehension and retention of information.

Evidence

Kluwin and Kelly (1991) examined dialogue journals of students obtained over the course of a year and found that, at least for some students, such writing applications improved written language outcomes. Walworth (1985) found similar results with a smaller sample of students. Most of the literature we found on writing applications described processes or procedures for implementing programs and activities. The data on outcomes relative to literacy were sparse, with the exception of content-area writing, which is reviewed in the following paragraphs under "Literacy Practice 6: Reading in the Content Areas." The LEA has a long history of support by teachers of children who are deaf or hard of hearing. However most of the literature is of a narrative or descriptive nature, suggesting ways to incorporate multiple elements of instruction into this approach. We found no articles comparing literacy outcomes of children taught using LEAs with outcomes of children not taught using LEAs. A weak research base supports the practice of incorporating writing as a tool to develop literacy, necessitating immediate remedies to warrant continued use of this time-honored practice.

Literacy Practice 6: Reading in the Content Areas

Reading in the content areas involves using content-area reading materials to promote reading comprehension through scaffolding and other content-area techniques.

Description of the Practice

Content-area reading refers to the challenge of reading in the academic areas of social studies, science, mathematics, literature, art, music, and drama. Specific skills are needed if one is to read well in the content area, among them identifying the main idea and supporting details, locating facts and specific details, organizing material into logical patterns, and adjusting reading rate for purpose, difficulty, and content. Students must be taught these skills so that they can apply metacognitive strategies to text. "Writing to learn" is a tool that has been used to help students construct content knowledge (Clearinghouse on Mathematics, Engineering, Technology, and Science, 2002). Writing to learn also helps teachers evaluate how students are interpreting activities and discussions and building new concepts. Some of the activities associated with writing to learn are guided free writing, end-of-class reflections, rewriting an excerpt, journal logs, graphic organizers, and data entry.

While literacy skills remain a crucial factor in comprehension and achievement in academic subjects, little is known about the impact on the developing reader of reading in the content areas. Strategies such as relating prior knowledge, clarifying, predicting, and restating, among others, should be applied when one is reading academic content, as well as when one is reading literature.

Evidence

Strassman (1992) studied deaf adolescents' approaches to school-related or content-area reading, focusing in particular on their application of metacognitive strategies. She found that most of the students she observed lacked mature metacognitive knowledge, relying more on skill-based and passive strategies. This resulted in the students being dependent readers of academic information. Yore (2000) built a persuasive case for the need to embed reading instruction and writing-to-learn activities within science material. Kelly, Albertini, and Shannon (2001) described a study of reading comprehension in deaf college students in the context of specific training in strategies for understanding science text. Those deaf students who were reading at a higher level showed greater improvements in comprehension than their counterparts reading at a lower level. In other words, the better readers can be taught to become better readers, who will in turn become even better readers. Strategies for reading and writing in the content area are mutually supportive and lead to improved literacy outcomes as well as comprehension and retention of information.

Students cannot be fully prepared in mathematics unless they are skilled at understanding text (Draper, 2002). Using literacy activities to engage students in a discussion of mathematics strengthens both mathematical ability and literacy. Borasi, Siegal, Fonzi, and Smith (1998) showed that encouraging students to talk, write, draw, and enact texts provided them with concrete ways to construct and negotiate interpretations of what they read. Barwell (2003) has pointed out that students' personal experiences have an impact on their ability to recognize relationships and solve word problems. The research base in this area suggests that this may be a best practice.

Literacy Practice 7: Shared Reading and Writing

Students engaged in shared reading and writing collaborate with others on activities that promote literacy development.

Description of the Practice

Shared reading and writing activities are most often associated with children who are at the emergent literacy stage, but these activities are of benefit to all students. Shared reading often involves the use of "big books," which are large books with large print that enable everyone to see the same thing at the same time. Storytelling and reading to others, as well as being read to by others, are components of the shared reading process. Sometimes language experience activities can be thought of as shared writing tasks. In shared reading, two or more individuals work together to unlock the meaning of print. In shared writing, two or more individuals work together to craft a written product. It is possible for a learner to draw on past experience or previous learning when trying to make sense of new information, but it is much more productive to have new information mediated through a teacher or parent. Almost all of early learning during the preschool years is mediated socially, so it might follow that young children learning to read would do so more rapidly with mediation from a teacher or parent.

Evidence

Luetke-Stahlman, Hayes, and Nielson (1996) provided an examination of some of the critical factors that should be involved in the shared reading process. Shared reading is based on the notion of mediated

learning, or learning that is presented through the eyes of another. This kind of mediated reading is highly successful with young deaf children of deaf parents (Maxwell, 1984), who tend to have higher reading levels than deaf children of hearing parents. Group storybook reading has been found to be highly motivating to young children who are deaf or hard of hearing (Gillespie & Twardosz, 1997), and has been shown to be effective with even the most delayed of preschoolers (Gioia, 2001). Collaborative or shared reading has more research support as a best practice in the literature on the developing reader than in the literature on the more mature reader.

Literacy Practice 8: Semantic Approach to Vocabulary

A semantic approach to vocabulary involves teaching vocabulary meaning through semantically based activities that enhance knowledge of multiple meanings of words, idiomatic expressions, and denotative (concrete) and connotative (abstract) meanings of words.

Description of the Practice

Paul (1996) detailed the "knowledge model" of vocabulary acquisition. This model proposes that vocabulary instruction should integrate new concepts into a student's semantic repertoire rather than focus on a particular context. Mere memorization of a list of words in order to be able to read an upcoming assignment, which Paul refers to as the traditional "definition-and-contextual (or -sentence) approach" (p. 11), is ineffective because it does not transfer to other contexts. The semantic-based knowledge model has three components: integration (e.g., semantic maps, word maps, and semantic features analysis), repetition, and meaningful use (i.e., encounters with words in deliberate and natural-learning contexts). In the semantically based approach, teachers explore vocabulary meaning in depth and as it relates to the child's whole world, rather than simply teach the use of the word that the child is going to encounter in an upcoming passage.

Evidence

Support for approaching the vocabulary within text by means of a semantics-based knowledge model can be seen in the mutual relationship between syntax and semantics (Kelly, 1996). Syntax influences word meaning dramatically. For example, rust can be a noun, a verb, or, when hyphenated, as in rust-colored, an adjective. Those students who are deaf or hard of hearing and who have higher levels of syntactic competence are better able to apply their vocabulary knowledge to a reading task. If a deaf reader's syntactic competence is limited, this may prevent that reader from getting access to stored vocabulary knowledge; thus, there is an interaction between the two elements. To enhance students' English literacy skills and help students expand their vocabularies independent of direct instruction, teachers need to teach them how to learn vocabulary from context, and context is constructed of a complex relationship between vocabulary meaning (semantics) and grammar (syntax and morphology). Better readers gained more from context than poorer readers when they tried to generate the meanings of unknown words in a passage (DeVilliers & Pomerantz, 1992). Semantics-based vocabulary instruction has a sufficient research base for it to be considered a best practice.

Literacy Practice 9: Morphographemic Approach to Vocabulary

A morphographemic approach to vocabulary entails teaching vocabulary meaning through morphographemic-based activities that enhance knowledge of word meaning through understanding of root/base words, prefixes, and suffixes, including Latin and Greek derivatives.

Description of the Practice

English-language word meaning is based on a highly morphemic system. That is, word meanings are expanded, modified, and changed routinely by affixing single and multiple morphemes to the front or end of a root word. The word antidisestablisbmentarianism comes to mind, in which establish is the root word modified by two prefixes (anti-, dis-) and four suffixes (-ment, -ary, -an, -ism). Others might parse this differently, but the point would be the same. In addition, rules of spelling (changing y to i) complicate the matter. If students who are deaf or hard of hearing are to read and write well, they must have facility with the morphemic system.

Evidence

Gaustad and Kelly (2004) compared the morphological skills of deaf college students and hearing middleschool students matched for reading achievement levels and found that even though the older deaf students were measured to be on the same reading level as the younger hearing students, the younger hearing students were significantly superior in the ability to understand the meaning of derivational morphemes and roots and to segment words containing multiple morphemes. Morphographemic approaches to teaching vocabulary are an important complement to semantic approaches but at present have only a developing research base.

Literacy Practice 10: Fluency

Specific activities and strategies can be applied to promote either spoken reading fluency in oral students or signed reading fluency in signing students.

Description of the Practice

Reading fluency is a complex topic that has until recently received very little attention. Reading fluency traditionally has been gauged by the number of words spoken accurately from a list or passage in a given time span (Hasbrouck & Tindal, 2005). For students who are deaf or hard of hearing and whose primary communication mode is spoken language, this definition may suffice, but how does one measure spoken reading fluency in children who do not speak? Visual fluency in signing deaf children entails rendering visual print into fluent, signed expression (Easterbrooks & Huston, 2001) involving the use of translation skills (Chrosniak, 1993).

Evidence

Reading fluency in students who are deaf or hard of hearing can improve with instruction (Ensor & Koller, 1997). Fluency involves the automatic rendering of print into a spoken or signed form (Chrosniak, 1993; Easterbrooks & Huston, 2001). Processing automaticity is "the ability to complete certain basic

operations of reading, such as word recognition and syntactic analysis, with a minimum of mental effort" (Kelly, 2003, p. 231) Processing automaticity is a primary source of the difference in comprehension between skilled and less skilled readers who are deaf or hard of hearing and is related to fluency. The research base on reading fluency in students who are deaf or hard of hearing may be said to be in its developing stages.

Mathematics and Science Practices

In this section of the present article we list the 10 mathematics and science practices that were researched, provide an expanded definition of each practice, then present the literature in support of the practice.

Mathematics and Science Practice 1: The Teacher as Skilled Communicator

The teacher should be a skilled communicator in ASL, spoken language, English-based sign systems, or other languages and communication modes used by students.

Description of the Practice

The evidence in all areas of education (i.e., regular education, deaf education, and bilingual education) is overwhelmingly dear that a teacher's ability to communicate is a crucial component of effective instruction. This is so well known a prerequisite that it is listed as one of the 10 standards of knowledge and skill required of all beginning teachers (Council for Exceptional Children, 2003). For teachers of the deaf, this means striving for nativelike skill in ASL, quality replication of English structure when using English-based sign systems, and a solid repertoire of techniques for making language comprehensible when using spoken language with orally communicating students.

Evidence

Children who have access to communication when they are young, whether that communication be in English or ASL, learn to communicate equally well (Spencer, 1993). The quantity of linguistic input directly relates to increased early language development (Goodwyn & Acredolo, 1993), yet quality communication is a problem for children who are deaf or hard of hearing because quality and quantity are not the same issues. While children who are deaf may be showered with quantities of communication, they cannot benefit from that communication if it is not in a format in which they may engage in uptake of the information (Gallaway & WoIl, 1994). Serrano Pau (1995) studied the influence of verbally presented mathematical problems and found that students who were deaf or hard of hearing and who were unable to understand the verbal presentation were also unable to solve the problems. The research base is dearly in support of considering good communication skills to be a best practice in the instruction of students who are deaf or hard of hearing.

Mathematics and Science Practice 2: Instruction Through the Primary Language

Instruction through the primary language requires teachers to provide science and mathematics concepts using the student's first language before competence is assessed in English.

Description of the Practice

Although similar to Mathematics and Science Practice 1, Practice 2 is different in that it recognizes that more than one language may be involved in the instruction of students with hearing loss. Teachers need to be skilled communicators in the first language of the students they are teaching. For teachers of the deaf, this may mean that if the students' first language is ASL, then teachers need to be proficient in ASL It is considered best practice for students to receive mathematics and science instruction in their first language before they are assessed in their second language (i.e., English). Evidence in the literature supports greater academic achievement in the content areas when teachers instruct students in their first language.

Evidence

The research on bilingual hearing students points to increased achievement when mathematics instruction is presented in the students' first language (Bernardo, 2002). This research has implications for the instruction of deaf students, in that it supports "first language" instruction as an effective approach for deaf students. Of 32 distinct characteristics of teachers, their ability to communicate dearly in sign language and to use clear examples in explanations is very highly valued by deaf students (Lang, McKee, & Conner, 1993). Hillegeist and Epstein (1989) studied deaf high school graduates and found that they exhibited poor understanding of concepts in algebra and mathematics. The authors concluded that one reason for this poor understanding was difficulty in finding an effective language in which those concepts could be taught and learned. The presentation features of sign language and teachers' sign choices create either bridges or barriers to deaf students' ability to solve word problems (Ansell & Pagliaro, 2001). Additional empirical evidence is needed to demonstrate differences in students' outcomes when they are instructed in their first language versus the language of preference of their teachers.

Mathematics and Science Practice 3: Teacher as Content Specialist

The teacher should possess specific training, experience, and certification in content-area knowledge of the subject being taught.

Description of the Practice

Teachers of the deaf need to have appropriate training in the content they are teaching as well as the practices they are using. For maximum student achievement in academic areas, teachers need to have a high level of competence or experience (or both). This assertion is based on the premise that additional content training increases teachers' content knowledge.

Evidence

The "highly qualified" requirements introduced by the No Child Left Behind Act compel exploration of whether deaf students are receiving the same quality of instruction as students who are being taught by content-area experts. It is not dearly evident that certification in content areas improves achievement of students who are deaf or hard of hearing, but there are studies that support the importance of content expertise. Teachers of students with hearing loss and such students themselves have both reported that content knowledge relates to perceptions of effectiveness (Lang et al., 1993). Schoenfeld (2002) found that when schools implemented mathematics reform curricula, the achievement gap between majority students and underrepresented students diminished. D. J. Wood, H. A. Wood, and Howarth (1983) surmised that discrepancies between hearing and deaf students' scores were related more to differences in their educational experiences than to hearing loss. To debate in the literature whether advanced levels of content-area knowledge are needed is moot, as they are now a federal requirement, and therefore a required practice.

Mathematics and Science Practice 4: Active Learning

Teachers should enhance concept mastery through the use of minds-on activities and materials that focus on active learning principles that cognitively engage students.

Description of the Practice

Minds-on, active learning requires students who are deaf or hard of hearing to apply critical thinking skills when this kind of learning is used in the teaching of mathematics and science concepts; this, in turn, ensures greater understanding and comprehension. The use of experiments, for example, requires understanding beyond Bloom's cognitive-domain levels of recall and comprehension (1956). It is important to challenge deaf students to analyze and synthesize content so that information becomes a tool for them to use in critical and active ways to solve real-world problems (Easterbrooks & Scheetz, 2004).

Evidence

Alternative mathematics teaching methods may be characterized as (a) building directly on students' entry knowledge and skills, (b) providing for both invention and practice, (c) focusing on analysis of multiple methods, and (d) asking students to provide explanations (Hiebert, 1999). Students who are deaf or hard of hearing and who have used minds-on materials in science inquiry tasks show improved scores in abstract categorization behavior (Boyd & George, 1973). Students who are deaf or hard of hearing and engage in experiential learning perform better on tests of delayed retention of knowledge than those taught in a lecture format (Quinsland, 1986). The research base for use of mindson, active learning is quite robust when describing older students but warrants additional attention regarding younger students who are deaf or hard of hearing.

Mathematics and Science Practice 5: Visual Organizers

Teachers should enhance concept mastery through the use of visual organizers such as graphs, charts, and visual maps.

Description of the Practice

A visual organizer is any visual or graphic tool that places information into a format in which the student may see, rather than hear about, the relationships among the concepts under consideration. Visual organizers are a favorite field-promoted practice in fostering content-area acquisition with students who are deaf or hard of hearing. A variety of visual organizers can be used, such as graphs, charts, and visual maps. Since most students who are deaf or hard of hearing are visual learners, logic compels us to support the use of visual tools in the instruction of all content.

Evidence

While there is ample evidence that graphic organizers and other such visual tools are deemed to be important for deaf and hard of hearing students based on historical practice (Luckner, Bowen, & Carter, 2001), few if any articles compare outcomes of use versus nonuse. Graphic organizers can be effective tools in helping students who are deaf or hard of hearing increase their use of adjectives in descriptive writing (Easterbrooks & Stoner, in press), and their use is an effective practice among hearing middle-school students who are deaf or hard of hearing when they are studying mathematics (Pape, 2004). The use of pictorial content and simplified English text produced significantly higher scores on comprehension of science concepts in one population of deaf students (Diebold & Waldron, 1988). Luckner and colleagues (2001) emphasized the need to use more visual strategies, since signing is a transient signal for deaf learners. Although the research base is sparse in this area, it may be said to be developing, and the trend toward positive research support is sufficient to recommend that the use of visual organizers be thought of as a probable best practice in deaf education.

Mathematics and Science Practice 6: Authentic, Problems-Based Instruction

Teachers should teach mathematics and science concepts by incorporating collaborative, case-based, real-world, or authentic problems allowing sufficient discussion time.

Description of the Practice

Authentic, problems-based instruction Is a strategy that incorporates real-world uses of information or authentic experiences when mathematics and science concepts are taught. Allowing students to work in groups and discuss solutions and questions to real-world problems gives meaning to concepts and improves comprehension of the abstract content.

Evidence

Stewart and Kluwin (2001) emphasized the need for authentic experiences in mathematics instruction. They stated that integrating vocabulary and creating greater opportunities for self-expression improve mathematics comprehension, and provided several specific activities for accomplishing this. The problem-solving method is often the one chosen by students who are deaf or hard of hearing when they are approaching word problems in mathematics. Moreau and Coquin-Vlennot (2003) conducted a study of 91 fifth graders in which they measured student selection of information found in word problems.

The students were divided into groups of high ability level and lower ability level, and the results showed that both groups chose the problem-solving method more often than the situational model.

There is a developing research base in support of the practice of problem-based instruction in deaf education.

Mathematics and Science Practice 7: Use of Technology

Teachers should use technology such as CDs, captioned materials, and interest-based Internet sites that are known to be motivating.

Description of the Practice

The use of technology to enhance content-area comprehension is consistently promoted in field-based articles and on various Web sites. Technology applications are increasingly available. There is a plethora from which to choose. Although we found little actual research to support this practice, it is implied that because these applications increase visual support, they can be very important in the instruction of students who are deaf or hard of hearing. Empirical data are needed on each of the different technology categories to determine the effectiveness of technology enhancements relative to time and cost factors.

Evidence

The available research indicated that technology can be useful in increasing students' comprehension in the content areas. Lang and Steely (2003) found that when information in science was presented using a "triad"-a short text screen, a corresponding animation explicating the text passage, and an ASL movie about the text-there were significantly greater knowledge gains for the deaf students than in traditional classroom experiences that did not include this triad. Several lists of practical computer applications for educators to use in mathematics instruction are available (Barham & Bishop, 1991); however, these technologies are not receiving the widespread use that might be expected (Pagliaro, 1998). No data-based articles were found comparing CDs as a category of tools to any other category of tools, although they continue to be mentioned in the literature under the category of visual materials that are appropriate for "visual people" (Lane et al., 1996, p. 116). Individuals who are themselves deaf rely heavily on computers (Zazove et al., 2004); this finding lends support to technology use as a practice worthy of recommendation and in need of research verification, particularly relative to time and cost expenditures.

Mathematics and Science Practice 8: Specialized Content Vocabulary

Teachers should teach science and mathematics using specialized content vocabulary, by means of either signs or fingerspelling, to increase content comprehension and promote group discussions and opportunities for selfexpression on specific topics. When an interpreter is used, the teacher should preteach the vocabulary and agree on signs for specialized content with the interpreter.

Description of the Practice

Specialized signs show students the context for abstract science and mathematics concepts. Although a variety of signs are often used for the same word, it is important that specialized vocabulary used in mathematics (e.g., ratio, integer) and science (e.g., Pleistocene, corpuscle) be presented consistently and in a manner that is standardized (or agreed upon) with students, to increase their comprehension. This practice is related to the idea that the educator be a "skilled communicator."

Evidence

Analysis of the language of mathematics reveals that it is complex and provides comprehension challenges to students who are deaf or hard of hearing, especially in the area of word problems (Kidd, 1991). Students who are unable to understand the verbal presentations of mathematics problems are also unable to solve the problems (Serrano Pau, 1995), a finding that suggests that teachers need to teach the language of mathematics to students who are deaf or hard of hearing. Limited exposure to mathematical language and the use of particular symbols in sign language increases misconceptions about geometry in deaf and hard of hearing students (Mason, 1994), and fluent use of mathematics vocabulary has been found to be a condition of mathematics achievement (Thompson & Rubenstein, 2000). While there is clear evidence that knowledge of the language of academic topics in the form of appropriate signs is a key to understanding academic instruction, there are no studies comparing use or nonuse of a coordinated and cohesive set of signs among all faculty and staff serving a student who is deaf or hard of hearing. This warrants further investigation.

Mathematics and Science Practice 9: Critical Thinking

It is permissible to begin with step-by-step strategies for problem solving in mathematics, but teachers should go beyond drill and practice to mathematics and science processes that require higher-order critical thinking and problem-solving skills.

Description of the Practice

Although drill and practice have a place in mathematics and science instruction, teachers need to extend their students' thinking beyond the basics to a problem-solving and higher-order-thinking approach. Step-by-step strategies used in problem solving with mathematics and science content are useful initially but limit the way in which a student will be able to apply the information to other life experiences.

Evidence

Hearing students with learning disabilities have demonstrated improved achievement in mathematical problem solving when receiving strategy instruction (Owen & Fuchs, 2002). Students who are deaf or hard of hearing do not perform as well as their hearing peers when there is more than one dimension to a problem (Ottem, 1980), perhaps because teachers of students with hearing loss tend to focus more on practice exercises than on true problem solving (Kelly, Lang, & Pagliaro, 2003). Deaf students tend to do better at solving math problems when teachers emphasize the complete problem-solving process, including the analytical and evaluative components (Kelly & Mousley, 2001). The trend in the literature

is toward support of higher-order critical thinking and problem solving as important practices for teachers of students who are deaf or hard of hearing.

Mathematics and Science Practice 10: Mediating Textbooks

The gap between the student's language abilities and the language demands of the textbook and the instructor should be addressed by scaffolding between the students' reading levels and the chosen materials.

Description of the Practice

A wide discrepancy between the reading ability of students who are deaf or hard of hearing and the demands of textbooks in mathematics and science is a chronic problem that teachers of the deaf must address in order to ensure access to grade-level content in mathematics, science, and other subjects. One way to accomplish this is through scaffolding. Scaffolding techniques include adding visual prompts, graphic organizers, and lower-level reading materials.

Evidence

Borasai and colleagues (1998) used transactional reading strategies to support content comprehension of hearing students. Their results showed that students who were encouraged to talk, write, draw, and enact information in texts had concrete ways to construct and negotiate interpretations of what they read. In one study, the use of highly pictorial content and simplified English text with students who were deaf or hard of hearing produced significantly higher pretest and posttest gain scores than formats with less pictorial content and more complex English patterns in the text (Diebold & Caldron, 1988). The available empirical evidence supporting modifications to reading matter is very limited, most support being in the nature of field-promoted practices. Additional data are needed on several aspects of this practice.

Conclusion

In the present article, we have listed 20 commonly used practices in deaf education, provided an expanded definition of each practice, and identified the literature in support of the practice. Some practices have more of a research base than others. Some additional literature has been added to the original body of work on which the present article is based (Easterbrooks, 2005; Lang & Kelly, 2005; Simmons, 2005).

The practices we have examined do not represent an exhaustive list of practices used. Indeed, the body of evidence regarding best practices in deaf education leaves much to be desired. Compared to the thousands of data-based articles available on the age-old communication battle (i.e., on the relative virtues of spoken language, signed forms of English, and ASL), the research on teaching and learning of academic subjects such as reading, writing, mathematics, science, and social studies is negligible. Of the hundreds of articles reviewed for the present project by multiple reviewers, only a few dozen met standards of rigor associated with empirical research. The remaining were quasi-experimental, case histories, questionnaires, or field promoted. However, the fact that we have limited proof that certain practices work does not mean that we do not have real-world evidence of their efficacy. We may not be

able to prove through the existing research evidence that a practice works, but neither can we prove that a practice does not work. We are left with the challenge of finding ways to gather sufficient evidence that the practices used in deaf education are legitimate practices for use with deaf and hard of hearing students. A combination of the literature across the range of evidentiary rigor, however, provides a glimpse at recommended practices in the field. Researchers in deaf education have much work to do.

Readers interested in a deeper analysis of the articles reviewed in the present article, including ratings of individual articles for research rigor, should go to the bulletin boards at www.deafed.net. Click on Bulletin Boards, then scroll down to Project Topical Teams, then click on 2.2 Content Competence.

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