USING STRUCTURED GAMES TO TEACH EARLY FRACTION CONCEPTS TO STUDENTS WHO ARE DEAF OR HARD OF HEARING

The study focused on the development of the concept of fractions in a group of 11- and 12-year-old students who were deaf or hard of hearing. The approach implemented in the study relied extensively on the use of games with very little formal instruction. It emphasized the development of appropriate language to facilitate an understanding of the notion of fractions through the investigation of concrete materials, pictorial representations, and interactions between students and teacher. The progress achieved by means of this approach is reported, and the implications of developing an understanding of fractions (and mathematics generally) among students who are deaf or hard of hearing are noted.

Educationally, the impact of reduced hearing is greatest in the area of communication and language development. The link between facility with language and literacy is well accepted (Power, 1990). The connection between language proficiency and thinking processes is also recognized (D. J. Wood, H. A. Wood, Griffiths, & Howarth, 1986). However, the importance of language in developing mathematical understanding and skills is not so widely recognized. Communicating thoughts, recognizing feelings, solving problems, and looking beyond the immediate are all part of what are currently acknowledged as goals for school mathematics (see, e.g., Australian Education Council, 1991, *A National Statement on Mathematics for Australian Schools*; National Council of Teachers of Mathematics, 2000, *Principles and Standards for School Mathematics*).

Daniele (1993) noted that people who are deaf require the same skills in mathematics as hearing people if they are to be participating, contributing members of society. Therefore, it is critical to resist the temptation to provide students “life skills” in mathematics if those skills reflect little more than drill with whole numbers, some computation, and a little work with fractions, decimals, and percentages. Daniele claimed that “school mathematics” must be much more than a study of formulas. It is an all-encompassing way of thinking, operating, and communicating. When the uses of mathematics are examined, they...
are all relevant to people who are deaf or hard of hearing. Mathematical understanding and mastery generates the power to be informed, to be responsible, to be independent.

Because of the difficulties many students who are deaf or hard of hearing experience with literacy, and because the same students are generally able to do simple computation, it is commonly believed that such students achieve acceptable levels of mastery in mathematics. However, the reality is that they have long struggled with mathematics in the broader sense because it involves much more than memorization and formulas. Barham and Bishop (1991) opened their investigation of mathematics and deaf children with the statement that “most teachers of deaf children, at both primary and secondary level, would agree that mathematics is one subject with which their pupils find special difficulty” (p. 179). Stone (1988) recognized the problem as “the tendency of deaf students to know better how to perform a mathematical operation than when to perform it” (p. 67).

Given the amount of research on the language development of students who are deaf or hard of hearing, there is a surprising lack of research on mathematics education for these students. Fridriksson and Stewart (1988) maintained that “mathematics is a neglected area in the total instructional component of a deaf child’s education.... Little attention is devoted to the conceptualization of mathematics principles and teachers rely heavily on drill and practice techniques” (p. 51). This assertion was supported by D. J. Wood et al. (1986), who, after investigating mathematical achievement of deaf students, concluded that reduced overall mathematical achievement among these students occurs because “many teachers teach the same some-

what limited curriculum to deaf children” (p. 164; see also H. Wood, D. Wood, Kingsmill, French, & Howarth, 1984). Kluwin and Moores (1989) suggested that teachers of the Deaf are not as familiar with current trends in mathematics education as their counterparts in hearing settings and that programs need to look to the organization of their mathematics programs and in-service training, with a focus on the content of mathematics curriculum.

The language of mathematics can be a very confusing domain (Spanos, Rhodes, Dale, & Crandall, 1988) and can create particular problems for learners who are deaf or hard of hearing. Students with reduced language proficiency will experience difficulty operating at a symbolic level, and because use of some language is specific to mathematics, it can be learned only in the context of mathematics. There are words that have a different meaning from their everyday use when used in mathematics (e.g., table), which can be a source of confusion until the mathematical meaning of such words is made clear. Another difficult aspect of the language of mathematics is that there can be many different ways of signaling an operation. Terms such as combine, sum, and increased by all imply addition without actually saying it. Spanos and colleagues examined the syntactic, semantic, and pragmatic features of English that are different in the mathematics register, and concluded that, at every level, the complexities of language used in a mathematical sense provide enormous challenges for the uninitiated: “Correctly manipulating the special vocabulary and phrases and the word order found in mathematics discourse is intricately tied to the ability to infer the correct mathematical meaning from the language” (p. 230).

The understanding and application of fractions is a basic mathematical skill required by all participating members of society. The language of fractions is complex, and is specific to the mathematics domain. Consequently, understanding fractions is a significant challenge for students who are deaf or hard of hearing. Silva has observed that “a fractions curriculum is very challenging to teach. Some of the challenge is because fractions look different from any numbers the [deaf] children have seen up to this point [in the mathematics curriculum]” (p. 126).

Titus (1995) found that older students demonstrate “whole number dominance” (p. 258); that is, when estimating fraction size, they are influenced by the size of the numbers in the fraction at the expense of reading the fraction as a whole. Titus considered a contributing factor to this situation to be the language used to describe fractions, and concluded that much of what has been found to be effective with hearing students in understanding fractions should also be useful with students who are deaf or hard of hearing.

Silva (1986) published a “fractions curriculum” for students who are deaf. She acknowledged the challenge of teaching fractions to these students and decided that a completely new approach was called for. From the beginning, students make wholes using the “rectangular model.” However, in Silva’s curriculum they are required to call wholes “gzorkes” and discuss fractions as part of a “gzorke.” Renaming of fractions is described in terms of “fattening” and “reducing.”

With this curriculum, multiplication of fractions was easily mastered by students—in 3 to 4 weeks. Silva found that students successfully completed a test a few weeks later and thus was assured of the effectiveness of her
program. Silva’s “fractions curriculum” is a departure from all that is accepted as good practice for teaching mathematics and teaching students who are deaf. Within this “curriculum,” there does not appear to be a sequential development starting from what students already know for the purposes of establishing what they need to know. It appears that the students move very quickly from learning about “gzorke” to calculating with equivalent fractions. The basic notion of fractions is completely bypassed by the substitution of the term gzorke for “whole.” It is difficult to understand why a new and irrelevant term such as this would be used with students who were acknowledged to be experiencing difficulty with language in the first place. Surely, the use of such a term would only complicate the learning process and distance students from the meaning of fractions.

Within a modern “constructivist” framework of mathematics teaching and learning, the mathematics classroom is full of activity and interactions because the constructivist view of mathematics is that concepts or realities are best developed through the mental “conflicts” experienced while one is actively solving problems. Students develop meaning from their own active inquiry and from interacting with other students or with their teacher. In the beginning, it is the materials themselves that capture the attention of the child. Through students’ continual engagement with these materials, thoughts about mathematics begin to take shape. Gradually, the materials become a vehicle for thinking rather than an end in themselves. Within a constructivist framework, teachers play a pivotal role in learning by providing activities that are appropriate and motivating, and by modeling meaningful discussion and coaching students who experience difficulty (Leder, 1993). It is also the teacher’s role to establish an atmosphere in which risk taking is accepted and all contributions are valued by being “enthusiastic, knowledgeable, nurturing, respectful, and trustworthy” (Blumenfeld, 1992, p. 276).

Teaching and Learning Fraction Concepts
There does not appear to be consensus among researchers as to the most appropriate approach to teaching fractions, but there are some points of agreement. There is agreement that fractions are not easy for students to understand, and that one of the difficulties can be found in their lack of knowledge of whole numbers. There is also no disagreement as to the value of teaching students about fractions. Researchers also agree that instruction in the area of fractions should be based on the principles of constructivism and should aim for understanding of the notion of parts and wholes (Pitkethly & Hunting, 1996).

Teaching Fractions
Though there are confusing messages from researchers, there is, at the same time, support for the philosophy of constructivism, with a solid base in the psychology of learning, that is available to guide program planners. A constructivist approach to program planning is described by Booker, Bond, Briggs, and Davey (1997). The program for teaching and learning of the early notions of fractions used by Booker and colleagues has been successfully implemented with hearing students (Booker, 1996a, 2000). It is based on the premise that students will develop the language to facilitate improved mathematical understanding through using it and seeing it used.

“Gamesing” approaches such as those described in the present study can help provide this language.

The Use of Games in Learning Mathematics
One way to generate children’s interest in the language and symbols of mathematics is through one of their favorite activities, playing games. Although games and related structured activities have been included in mathematics programs chiefly to motivate children or to reward them for progress, the interest generated by games can also be used to help children generalize to the more abstract recorded forms and higher-level mathematical ideas (Booker, 1996b, 2000).

For most children, the introduction of games to the classroom generates excitement and involvement. In addition to motivating students to be actively involved in mathematical activity, games add variety to the mathematics program. Because of the interactions that occur between participants, games provide for discussion among students and between students and their teacher. In terms of constructivist theory, games supply a rich and stimulating social context for mathematical learning (Booker, 1996b, 2000).

The Research Study
Four students (2 boys and 2 girls) participated in the present study. At the time of the study, they made up half of the Year 6/7 class in a unit for deaf students in a regular elementary school. These particular students did not grasp mathematical concepts easily: The other Year 6/7 students were integrated into a regular Year 7 class for their mathematics program.

The 4 students represented a range of hearing impairment and a variety of preferred modes of communication.
Two of the students were profoundly deaf and relied on signed English communication. The other 2 students, although they knew some sign, had sufficient hearing to operate orally. Mathematical assessment with the Booker Profiles in Mathematics (Booker, 1995) showed that all 4 students had a general lack of understanding of the number system, operations on numbers, and problem-solving applications. Overall, although the students were nominally in Year 6/7, they were actually operating at approximately the Year 3/4 level in mathematics.

The Program for Teaching and Learning of Fractions

The teaching program was tightly sequenced to move the students through a number of steps, expanding their notion of fractions as they went. It offered them the opportunity to experience fractions in a very concrete way, surrounded by appropriate language and the opportunity to use this language. Games were provided that required the students to make a match between the pictorial representation of a fraction and the appropriate language. They were also required to compare fractions, match equivalent fractions, and work with fractions of a group. The entire program consisted of games and activities with minimal use of traditional “teacher talk-centered” methods. Throughout the project, the students were continually required to explain their thinking and to justify their answers. Initially they were uncomfortable with this procedure, interpreting instances of its use as indications that they were giving incorrect answers. Consequently, they would promptly change their answers. However, after some time, they realized that they would be asked to justify their answers whether they were correct or incorrect, and the procedure became accepted as routine.

Through the variety of games and activities that were used, the students maintained interest in and developed a basic understanding of the notion of fractions. The games were devised to meet specific instructional goals and, at the same time, to make the learning process enjoyable and boost self-esteem. They also provided a vehicle for the teacher to gain insights into how the students were thinking and to contribute to the construction of their understanding through discussion related to the games and activities.

The interactions that occurred during the project were of particular interest. The lesson transcripts show many interchanges of a mathematical nature. Students questioned, answered questions, and commented on what was happening. In his or her own way and at his or her own pace, each student was involved in and contributed to discussions about mathematics. However, it is significant to note that a large number of mathematical interactions were between a student and the teacher. There were few interactions of a purely mathematical nature between students; most student interactions related to procedural matters such as instructions, which color pen to use, accusations of cheating, or whose turn it was.

The reasons for the scarcity of student-to-student discussion are open to speculation. Is it that these students lacked experience in mathematical justification and reflection, and, hence, the skills needed to discuss mathematics? This may well have been a significant factor in the scarcity of mathematical discussion, as these students were accustomed to manipulating materials, but only in response to teacher directions and not as a stimulus to discussion. Is it that diminished mathematical interactions were associated with discussing abstract concepts within the framework of delayed language development? This is also a possibility, as none of the students had age-appropriate language development.

Was Student Discussion Stifled by Inappropriate Levels of Teacher Control?

To investigate whether the teacher inhibited student discussion, a method of analysis developed by D. J. Wood (1985) was used to search for some indication of whether the teacher was excessively “controlling” and hence interfering with the students’ learning in a program based on constructivist principles. Thirty consecutive pairs of utterances were analyzed by means of Wood’s “Moves Matrix.” Controlling utterances by teachers in the mathematics lessons were found to constitute 50% of all utterances. Comparison with findings from other Australian research in situations that were more conversational than instructional (Power, D. J. Wood, & H. A. Wood, 1990) indicated that the level of control in the mathematics lessons was within the medium range, and, indeed, slightly lower than the average (56%) reported for conversations between deaf students and their teachers. Student initiative (i.e., turns in which the student spoke first) was rated at 53%, also within the medium range, and also slightly lower than the average (57%) reported by Power and colleagues (1990) for Australian students’ initiative in conversations. Hence, it appeared that the teacher was not overcontrolling interactions to the point where student initiatives were being stifled. H. A. Wood and D. J. Wood (1984) acknowledge the need for a degree of teacher control in didactic situations: “Thus, in situations
where...a teacher needs to...lead children through a difficult line of reasoning...then question after question will keep the focus of power in the hands of the person best qualified to wield it” (p. 56). Because, in the framework of the present study, the level of teacher control in an instructional context, teacher control seemed unlikely to be a pivotal factor in the low level of mathematical discussion among students.

Another important aspect of the inquiry into the type of interactions that occurred in the project is “dual attention” (D. J. Wood et al., 1986). When signed or spoken communication occurred, the students had to choose where to focus their attention: the signer/speaker or the materials being discussed. This is a cognitively challenging task, as they had to make the semantic connection between two things separated in time and space. Furthermore, when students wanted to contribute to the discussion or make a comment, they were only understood by those who were watching if the message was signed or those who could hear if they spoke without signing. These were not ideal conditions for spontaneous sharing of information. To minimize the effects of this situation, certain factors must come into play. First, there must be awareness of student needs by the teacher, who can then modify his or her communication style by giving students time to shift attention from communicator to referent. Second, students themselves have a role to play by similarly modifying their communication style for their peers and by taking responsibility for watching appropriately when important matters are being discussed.

**Outcomes**

Within approximately 25 hours of class time, students who had been considered slow developers in mathematics understood fractions and were using them in a practical way. Each participated at his or her own level, according to his or her own skills and preferred mode of communication. All of them, in general terms, enjoyed the project, felt good about their personal involvement, and gained some self-esteem through seeing themselves as successful learners in an area where previously they had had difficulty. Further details of all aspects of the present study, including the games used, can be found in Markey (2000).

At the completion of the project, the students understood that fractions are made up of equal parts, whose number can change. They understood the conventions of fraction names, although some of the students were not consistent in using them expressively. The students also showed that they understood and could manipulate fractions regardless of whether they equaled more or less than one whole. They were intrigued by the idea of equivalent fractions and attempted to identify them. They also grasped the concept of fractions of a group and manipulated such fractions without difficulty. The project provided a motivating and effective approach to teaching a basic understanding of fractions.

In terms of the quest for an effective approach to developing mathematical understanding in students who are deaf or hard of hearing, the present study provided several optimistic findings. The value of an approach like this for such students is evident, because at every level meaningful language was promoted and the students were given opportunities to observe its use, and were encouraged to employ it in their endeavors to exchange meaning in the group. The examples of their use of the language of fractions give cause for confidence in this approach to developing meaning and using appropriate language in association with each other. Certainly, the students would require further experience and reinforcement in the use of mathematical language, but it is clear that their understanding and use of the appropriate language was developing well by the end of the study.

In keeping with the expectation that interactions would be desirable because they would facilitate the use of language, enhance negotiation of meaning, and provide clarification of concepts, it was found that there were many instances in which interactions characterized by these benefits occurred. The games and activities involved the students in the learning process and motivated them to maintain their interest. There were examples of students clarifying their own thinking and questioning each other’s understanding through games that obliged the students to listen to others and describe their own understanding because of the need to make decisions and negotiate meaning. In team games, the students’ competitive tendencies also compelled them to watch the moves of the opposing team lest it gain an unfair advantage, again providing opportunities for meaningful use of language.

Although there were many examples of positive interactions during the study, a significant proportion of them were between a student and the teacher, and interactions among students tended to be single sentences rather than longer discussions. The reason for this is uncertain, but it is likely that it was due in part to their lack of experience with this style of
learning. It was anticipated that as the students became more experienced with this style of learning and more confident that their peers would accept their contributions without censure, they would be likely to enter into more interactions.

Certain games resulted in more discussion than others. The team games worked best because the students enjoyed each of the activities and also because their competitive streak impelled them to participate in order to win. Games that compelled the students to make requests of others facilitated more interactions than those requiring only the manipulation of materials.

Students showed evidence of responding positively to the affective aspects of learning made possible by the structured-games approach. They indicated by their words and actions that they had a positive attitude toward themselves and what they were learning. Three of the 4 students evidenced significant changes in behavior during the study. One student who was well practiced in work avoidance techniques did not once attempt to evade any part of the mathematics program, despite the fact that she was being challenged by the mathematical content. The student who appeared to have the lowest self-esteem and least expectation of success verbalized his preference for the “gamesing” activities over written exercises, in addition to verbalizing his delight at his instances of success. His self-deprecating comments did not end, and his fears were not extinguished, but they were both outweighed by regular expressions of pleasure at his own success. The student who experienced the greatest difficulty with cooperating and exhibiting calm, focused behavior achieved a gradual but noticeable improvement in his cooperation and application to the activities. Students benefited from individual interactions with the teacher, which were made possible not only by the small number of students but by the other students’ interest in the activities, which sustained them while the teacher was focused on one student. Therefore, it is clear that the games and activities not only provided a suitable basis for mathematical learning that was motivating and interesting and met the students’ educational needs, but also created the basis for a way of learning that was nonthreatening and boosted self-esteem as well as a positive attitude toward mathematics.

The problem of “divided attention” is not a reason to abandon the structured-games approach to developing mastery of mathematics. Students are faced with similar difficulties when involved in science experiments, in group reading situations, when watching interpreted videos, when skills are demonstrated in a physical education lesson, and in many other common educational situations. The question is one of awareness and how teachers can best manage the learning situation to accommodate their students’ needs.

The outcomes of the present study point to the suitability of a “gamesing” approach to developing mathematical understanding of students who are deaf or hard of hearing. In addition, it emerges as a potential key to meeting the specific needs of such students who require an alternative mathematics program because of the way in which it relates meaning and language and allows students to work at their own pace.

**Future Directions**
The quest for improvements in the mathematical understanding of students who are deaf or hard of hearing is far from complete. It is not acceptable for significant numbers of students who are deaf or hard of hearing to complete their school years with little or no real understanding of mathematics and its uses. If this happens, any social disadvantage they experience because of their deafness will be magnified. Competence in mathematics is as important in society as competence in literacy. The two are complementary skills that empower individuals to be informed, to participate at an acceptable level, and to improve themselves. Therefore, teachers must make a professional commitment to “quantitative literacy” (Daniele, 1993) to improve the current situation of underachievement in mathematics by these students. However, for this to occur, some things must change. We suggest that teachers of students with hearing loss will require better-than-average knowledge of mathematics education and familiarity with techniques in identification and remediation of difficulties in mathematics learning. A change in the attitudes of teachers of the Deaf is necessary in the form of a general acknowledgment that current efforts and approaches are inadequate and that the key to improvement lies in innovation. Professional development needs to focus on current approaches to teaching and learning mathematics and on in-depth techniques for assisting students with difficulties.

Constructivist approaches to teaching and learning mathematics appear to offer a worthwhile alternative to traditional methods. Further research on the implementation of constructivist approaches to teaching mathematics to students who are deaf or hard of hearing should be undertaken to build upon the information generated by the present study. In
keeping with this approach to teaching and learning and the emphasis on discussion and exchange of meaning between students, further information on strategies or techniques for promoting discussion among students who are deaf or hard of hearing would be particularly beneficial. An environment of acceptance and teachers’ use of low-control contributions to discussions can surely help foster dialogue among students, but there nonetheless appear to be other factors affecting students’ lack of a propensity to involve themselves in discussion. Information on the nature of these factors might advance the implementation of an approach that would induce students to involve themselves more in discussion and hence to experience improved learning outcomes across the board.

There can be no doubt about the importance of language within the mathematical arena as a means of building and conveying understanding and meaning. Accordingly, it would be worthwhile to identify the types of linguistic structures and the features of greatest consequence in the various levels of mathematics, and then to relate this information to the wealth of information on language development of students who are deaf or hard of hearing. This information could alert teachers to possible sources of difficulty for students and content areas that warrant special attention.

Just as language is a source of difficulty for most students who are deaf or hard of hearing, so too are symbols. There is often confusion as to the value of symbols because they are often regarded as a source of visual information, the meaning of which is obvious and freestanding. Symbols are, by definition, abstractions, and, as such, have the potential to be the source of a great dilemma for deaf students. Symbols have no meaning in themselves; they are endowed with meaning by the ideas that lie behind them. Furthermore, fraction symbols are a departure from the whole-number symbol system deaf students have experienced, and have the potential to be even more confusing if the meaning behind them is not understood. Consequently, research on the impact of the symbol system in mathematics and strategies for introducing and using symbols with deaf students would provide engrossing reading for those involved in teaching mathematics.

Difficulties with “divided attention” are experienced in all subject areas. There is awareness of its existence and some provision for the different learning styles it necessitates. Nevertheless, details on the most effective techniques and strategies for reducing its impact are scarce. It appears logical that those who would have most to offer in this regard are the Deaf themselves, and those who would have most to gain would be students who are deaf or hard of hearing and their teachers and parents. Further research into styles of teaching and, in particular, using materials that minimize the difficulties arising from “divided attention” would be helpful.

Other future directions for improvements in mathematical outcomes for students who are deaf or hard of hearing include:

- professional development that focuses on current developments in mathematics education as well as techniques in diagnosis and remediation of students experiencing difficulties in mathematics further research into the utilization of constructivist approaches with students who are deaf or hard of hearing in other areas of mathematics
- more information on factors affecting the seeming lack of propensity of students who are deaf or hard of hearing to engage in long discussions
- further research on the effective use of mathematical symbols with students who are deaf or hard of hearing
- information on the most effective strategies for reducing the impact of “divided attention” on students who are deaf or hard of hearing

So the challenge continues in many different guises. Language is not only a subject within itself, it is an integral part of everything in the education of students who are deaf or hard of hearing. Mathematics is not just numbers and operations on numbers, it is also a different application of language which, in turn, fosters understanding and improvement in mathematics. Somewhere in the alliance between language and the understanding of mathematics lies the key to improved mathematical outcomes for students who are deaf or hard of hearing and the empowerment that accompanies these outcomes.

**Note**

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