Discovering mathematics: The challenges that deaf/hearing-impaired children encounter

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This paper reports on difficulties that deaf/hearing-impaired children may encounter when learning mathematics in early childhood settings. The objective was to enhance teacher practice by identifying possible ways in which barriers to learning could be overcome. The key issue arising revealed that deaf/hearing-impaired children's limited language base may prevent them from understanding and developing mathematical language. Other related issues that influenced mathematical development were parental involvement and comprehensive support in the home environment, together with a greater emphasis on the use of mathematical resources and specific strategies for teaching mathematics to deaf/hearing-impaired children.

Rationale

Many things in our everyday lives have a mathematical basis, whether we are counting out money at the supermarket or calculating whether we have enough room to squeeze our car into a particular parking space! Today's society is technologically-oriented, and information-rich, and children need to develop mathematical skills in order to have the confidence and competence to be effective participants in our technological society.

In New Zealand, early childhood centres are required by the Ministry of Education to base their educational programmes, assessment/evaluation procedures and centre policies/practices on the early childhood curriculum document *Te Whaariki* (Ministry of Education, 1996). This document is used to create learning environments that are meaningful for children, meet their individual needs and encourage learning in an holistic, equitable and culturally sensitive way. *Te Whaariki*, with its constructivist foundations can be linked with the national mathematics curriculum (*MiNZC*) (Ministry

of Education, 1992) to develop mathematical thinking in young children. However, the reality for many deaf/hearing-impaired children is that they find it difficult to learn mathematical content/processes and to interpret and understand the language of mathematics.

Learning mathematical content

The constructivist approach to learning mathematics relies on children developing their own unique understanding of mathematics and places emphasis on how children "come to know" (Begg, 1995: 1). Meadow-Orlans (1980) states that mathematical concepts can be learnt by deaf/hearing-impaired children in the same sequence and manner as their hearing peers, and this raises the issue of differences for hearing and deaf/hearing-impaired children in terms of how their learning environment caters for this 'coming to know'.

With all children, the understanding of mathematical concepts involves considerable experience, with particular problems being presented in familiar and different ways. In early childhood settings, developing and enhancing children's mathematical knowledge requires teachers to facilitate learning experiences through play that are meaningful, spontaneous and which allow children's existing knowledge to be built upon, while at the same time constructing new knowledge. Haynes (1999: 143) states "Concept-learning should be taught in such a way that children develop the ability to think mathematically and new experiences should allow them to refine their existing knowledge and ideas in constructing new knowledge". While Meadow-Orlans (1980) states that mathematical reasoning is no different in deaf and hearing children it is noted that the learning process is slower in deaf/hearing-impaired children. Pau (1995) attributes this to many deaf/hearing-impaired children having experiential deficits and receiving different treatment from their teachers in the learning environment.

Mathematical processes

Engagement in mathematical processes such as problem-solving, developing logic and reasoning and communicating mathematical ideas depends upon children having good communication skills. Much of the information that hearing children learn about language is picked up incidentally from their environment. In comparison with their hearing peers, deaf/hearing-impaired children miss out on various concepts and vocabulary that hearing children pick up incidentally. Flexer (1999: 14) notes that "...a child with a hearing problem may have a limited range or distance of hearing; that child may need to be taught directly many skills that other children learn incidentally".

Deaf/hearing-impaired children find it difficult to understand verbal and written mathematical problems. Pau (1995) states that in order to solve written problems correctly deaf/hearing- impaired children need to correctly interpret every one of the words contained in the problem's text. In terms of verbal problems deaf/hearing-impaired children attempt to simplify the problems by converting them into understandable linguistic forms. Pau (1995: 290) suggests that "It is therefore vital that any teaching programme designed to improve the child's problem-solving level should include general text-comprehension and, in particular, mathematics text-comprehension activities".

Barton (1995) notes several distinct features of mathematical language which make it complex and foreign for many learners, including having familiar words with precise meanings that differ from their normal meanings. This would suggest that the interpretation of the language of mathematics with its ambiguous vocabulary is particularly challenging for deaf/hearing-impaired children.

The learning environment

A beneficial learning environment encourages and enables children to construct their own meaning out of mathematical problems, because as Haynes (1999: 143) notes "Infants and toddlers learn predominantly through their senses and motor skills, therefore their physical environment is of utmost importance". When children are given responsibility for their own learning, individual styles of learning are catered for and a variety of resources are made available to meet children's individual needs.

The make-up of the learning environment is particularly crucial for deaf/hearing-impaired children as compared to their hearing peers they are always at a disadvantage because information is generally received via the spoken word. The structures of language may not necessarily be in place in deaf/hearing-impaired children and many find it difficult to communicate through language in the same way as their hearing peers.

Gathering the data

The study involved four participants, two of whom were itinerant teachers of the deaf in a city in New Zealand, and two were children in kindergartens. The two mainstream kindergartens involved in the investigation catered for children from middle to high-income families and served a community of both European and a variety of ethnic groups. Information was gathered through questionnaires from the two itinerant teachers of the deaf, together with follow-up interviews, and observations of one deaf/hearing-impaired child in each of the kindergartens.

The purpose of the questionnaire was to establish teachers' perceptions of the challenges that deaf/hearing-impaired children may encounter in learning mathematics. The data identified five issues that the itinerant teachers were in agreement upon. Follow-up interviews were then carried out with the itinerant teachers to gather more information on the teachers' views relating to those five issues. Observations of the children were recorded as learning stories (Carr, 1998). The learning stories were analysed using the

five content areas of the mathematics curriculum to establish whether, and to what extent, mathematical thinking was occurring in the children's play/activities.

Findings

The investigation found that various factors prevent deaf/hearing-impaired children from successfully constructing mathematical knowledge. One core theme, language and mathematical language acquisition, emerged together with four further influences on mathematical development:

- cognitive development and the influences on mathematical development
- background noise and engagement in mathematical processes
- mathematical resources
- partnership with parents

Language and mathematical language acquisition

The core theme involved deaf/hearing-impaired children's acquisition of language/mathematical language and the effect that a limited language base has on deaf/hearing-impaired children's mathematical learning. The teachers believed that deaf/hearing-impaired children lack the basic mathematical, or even general, vocabulary needed for them to be able to understand mathematical concepts/processes. Pau (1995: 4) has suggested that "verbal arithmetic problems contain certain linguistic forms which are particularly difficult for deaf subjects." One teacher noted that without a basic understanding of nouns, verbs etc, deaf/hearing-impaired children have no idea what questions are being asked of them and thus what is expected of them. Barton (1995: 158) states that for children learning the language of mathematics:

> in the early days of vocabulary development it was important that the words selected help understanding rather than present a new item to be learnt. It was realised that if base words could be built upon to form vocabulary for

> more complex terms, then mathematics learning could go hand-in-hand with vocabulary learning.

In contrast to their deaf/hearing-impaired peers, hearing children are exposed to language from birth and have an understanding of everyday language. This acts as a launching pad for developing their understanding and use of mathematical language. Flexer (1999: 14) notes that "a child with a hearing problem may have a limited range or distance of hearing; that child may need to be taught directly many skills that other children learn incidentally". The implication of this for teachers is that they need to be aware of, and focus on, those areas of learning or language skills that deaf/hearing-impaired children find particularly challenging because it is more difficult for them to incidentally acquire those skills from their environment.

One teacher in the investigation noted that deaf/hearing-impaired children, to a certain extent, are unable to take part in group activities/discussions because they do not have the language required. Mathematical or cognitive concepts which involve specific language related to volume, shape, size, comparisons, measurement and reasoning are particularly difficult for deaf/hearing-impaired children to grasp. This relates to Barton's view (1995: 160) that

> mathematics discourse has distinct features not found in normal English. For example, it is particularly dense, it is very precise, it is read in multiple directions (not just from left to right), and it contains familiar words with precise meanings which are different from their normal meanings.

The challenges that deaf/hearing-impaired children encounter with regard to language/mathematical language were also evident during my observations of the children, when it became apparent that the children did not understand concepts such as in front of, behind, under, same, different.

One teacher felt that with a limited language base it is difficult for deaf/hearing-impaired children to solve mathematical problems beyond a basic level. Mousley and Kelly (1998) suggest that several factors contribute to the difficulties experienced by deaf/hearing-impaired children with regard to problem-solving and general reasoning skills. These factors include difficulties in building meta-cognitive skills and the tendency of many deaf/hearing-impaired students to proceed too quickly when attempting to solve a problem rather than pausing to think it through or develop a coherent plan

Cognitive development and the influences on mathematical development

The data revealed that both teachers felt that deaf/hearing-impaired children are not cognitively different from their hearing peers and Meadow-Orlans (1980) indicates that there is evidence to suggest that deaf children learn concepts in the same sequence and in the same manner as hearing children do. However Flexer (1999) suggests that hearing impairment, whether slight or profound in nature, if unmanaged, can have a negative impact on the development of not only spoken language but also academic competencies. One teacher noted that deaf/hearing-impaired children's overall learning, including mathematical learning, is generally delayed because of a limited language base.

Both teachers felt that when mathematical concepts are taught 'visually' they are easier for deaf/hearing-impaired children to understand. One believed that signing-children, being visually oriented, are perhaps more likely to find it easier to adapt to the written form of a number than a hearing child because they are more focused on visual things. I observed that the children were more likely to attempt, and in due course understand, a mathematical problem when they used hands-on, visually engaging mathematical activities and resources.

The teachers in this investigation felt that in order for deaf/hearing-impaired children to develop cognitively, particularly in a mathematical sense, they needed to be introduced to

a diversity of mathematical experiences along with a rich language base. Haynes (2000: 100) comments that "as children play, and think mathematically, they are engaged in thinking across all content strands". This suggests that deaf/hearing-impaired children also, as for all children, should be presented with a wide variety of experiences in order to extend the opportunities for them to engage in mathematical thinking across the range of content strands of the mathematics curriculum (Ministry of Education, 1992). Learning experiences might include:

- number - using play money to represent numbers, finding halves and quarters of everyday objects such as the division of a sandwich/cake
- measurement - estimating and measuring using bottles/containers at the water-trough
- geometry - exploring space and shape by putting items inside, on, behind, in front of other objects
- algebra - exploring patterns and relationships by arranging coloured bears in a repetitive sequence
- statistics - the sorting of pictures and objects like personal clothing, washing.

Measurement is a concept that both children appeared to find particularly difficult to understand. I observed that when a toy truck was propelled along the floor with/without a full load, and the distance it traveled was measured, the children were unable to express either by word or gesture that they understood the concepts of length/distance, lighter/heavier or faster/slower. Mousley & Kelly (1998: 335) have said that "the internalization and application of new knowledge and skills is enhanced by repetitive practice, active participation, interactive discussion and evaluative feedback". Both teachers confirmed that deaf/hearing-impaired children need to receive constant repetition of mathematical concepts in order to retain them.

Background noise and engagement in mathematical processes

Engaging in mathematical processes such as problem-solving, developing logic and reasoning and communicating mathematical ideas depends upon children having good communication skills. It is crucial therefore that the learning environment allows for ease of communication. *Problem-solving* is a skill that both teachers saw as problematic for deaf/hearing-impaired children in terms of their communication skills. Problem-solving requires children to use their observations to make predictions, which in turn requires a sound language base. My observations revealed that when displaying statistical thinking, i.e., sorting pictures of clothing, food and animals into categories, the children did not understand what was being asked of them. They followed the direction of the teacher's eyes in order to correctly categorise their pictures, or required a lengthy and repeated explanation from the teacher before they began to grasp the concept.

The *development of logic and reasoning* in young children generally begins with the classification of objects, numbers and ideas within a range of meaningful contexts. Johnson (1993, cited in Davis, 1996) suggests that an individual develops logical thinking when language skills are sufficiently developed to allow that person to construct chains of casual thought. Deaf/hearing-impaired children's ability to successfully interpret mathematical information/results and to use words/symbols in a mathematical context would be disadvantaged by their level of development of communication skills.

Communicating mathematical ideas involves children using their own language and the language of mathematics to express mathematical ideas. As already discussed Barton (1995) believes that learning mathematics is like learning a language. For some deaf/hearing-impaired children the language of mathematics features as their third/fourth language, after New Zealand Sign Language, English, and sometimes a non-English home language. This is challenged by Barton's idea that

> the process of using more than one language to express mathematical ideas is additive in itself. That is given sufficient proficiency in both languages,

> students are liable to have better understanding because they have two modes in which to think and communicate. (p.159)

However, both teachers comment that deaf/hearing-impaired children do find it extra difficult to communicate the results of their mathematical explorations to their peers and teachers.

The teachers believed that various environmental distractions prevent deaf/hearing-impaired children from successfully constructing mathematical knowledge. In busy/noisy environments deaf/hearing-impaired children find it challenging to focus on the teacher's voice and the task at hand. One teacher mentioned that it takes longer for deaf/hearing-impaired children to learn to identify and discriminate between sounds, a skill that their hearing peers have practised, and ultimately mastered, from when they were babies. The need to close the gap between deaf/hearing-impaired children's and hearing-children's mathematical learning is a goal referred to by one of the teachers.

An appropriate physical environment is a crucial component for successful mathematical learning for all children and Haynes (1999) supports the importance of the physical environment for early childhood settings, in particular, where children learn very much through their senses and motor skills. The teachers felt that the many distractions/noises experienced in a busy learning environment are the principal reasons for working one-on-one, or in small groups, with deaf/hearing-impaired children, in an area detached from the other children. A source of tension arises for teachers when faced with carrying out essential auditory skills programmes with children, which necessitate minimal environmental noise/distractions. At the same time they are endeavouring to address the principles of *Te Whaariki* (Ministry of Education, 1996) in terms of child-initiated rather than teacher-directed learning. One teacher noted that on occasions when children are withdrawn the principles of *Te Whaariki* are still being met by assisting the deaf/hearing-impaired children to develop their language, sense of belonging, their ability to communicate and their sense of self-worth/well-being.

Mathematical resources

The teachers believed it to be paramount for deaf/hearing-impaired children to experience mathematics in a concrete and meaningful way in order to develop an understanding of mathematical concepts/processes. Haynes (1999) writes that concept learning should be taught in such a way that children develop the ability to think mathematically, experiencing new learning situations which allow them to refine their existing knowledge and ideas in constructing new knowledge. She emphasises the integral role that teachers play in developing young children's mathematical learning through supporting them to make mathematical sense of their world. This highlights the need for early childhood teachers to have the mathematical knowledge to capitalise on resources provided for children's play. Haynes (2000) focuses on the gains to be made in children's mathematical learning, by accenting the importance of informed insight into the creation of environments which are meaningful in terms of a child's personal context. This study revealed that the teachers believed that some teachers do not make efficient or frequent use of the mathematically-rich resources available to them in their early childhood centres. One teacher noted that too often resources are ignored because of the time involved in using them, the energy needed and the fact that classes/groups are generally too large.

One of the teachers stated that the use of mathematical resources is an area that needs further input in terms of the training of the teachers of the deaf. Professional development should include strategies for teachers to focus on the resources suitable for deaf/hearing-impaired children in particular, and the best ways of using resources to generate mathematical thinking. Pagliaro & Roudybush (1998: 373) write that research results reveal that there is an "insufficient level of mathematics preparation among deaf education teachers". They found that few teachers of the deaf hold qualifications with a focus in a mathematics-related field and only a moderate number have sought professional development in that discipline. They believe that it is imperative that

> researchers should investigate mathematics instruction and learning within deaf education with more frequency and depth, so as to provide a better education to deaf and hard of hearing students (p. 27).

To enhance even further the children's mathematical learning through appropriate use of resources, both teachers believed that the onus is on teachers to take every opportunity to use mathematical vocabulary alongside appropriate resources to consciously provide richer opportunities for mathematical learning.

Partnership with parents

Both teachers believed that it is important that there be on-going communication between the home and teachers so that mathematical vocabulary is being repeated and re-inforced in as many different situations as possible. One teacher felt that because deaf/hearing-impaired children take so long to understand mathematical concepts due to a lack of language, it is crucial for the children to have those concepts repeated in a variety of contexts with different materials and people. The other teacher suggested that there were unlimited opportunities in the home to experiment with those mathematical concepts including when sorting out the washing/shoes, or working in the kitchen, or in fact engaging in any routes of a normal day.

Haynes (1999: 142) states that "In order to maximise the learning the adult must ensure that purposeful play experiences, within an enriched environment, offer challenges and opportunities for exploration and problem-solving". Hearing children are likely to hear mathematical concepts mentioned incidentally during any given day but for deaf/hearing-impaired children the concept has to be deliberately brought to their attention in as many ways and as often as possible. Parents and teachers need to work together as a team to

reinforce mathematical vocabulary and concepts. In order to achieve this, communication has to be on-going between parents and teachers.

Conclusion

The challenges that deaf/hearing-impaired children encounter when learning mathematics are many and far-reaching, and several issues have been identified in this paper which act as a barrier to deaf/hearing-impaired children's mathematical learning. Deaf/hearing-impaired children find it challenging to develop mathematical learning because they generally have insufficient language skills upon which to base mathematical language. Problem-solving is particularly difficult for deaf/hearing-impaired children as a sound language base is needed for putting observations into words or making predictions. Without these language skills deaf/hearing-impaired children become isolated in the learning environment and are unable to participate fully in group activities and mathematical discussions.

In order for deaf/hearing-impaired children to develop cognitively, particularly in a mathematical sense, the learning environment must have a wide range of meaningful mathematical experiences that are *visually* engaging and hands-on. Activities should be purposeful and have relevance to everyday life so that they can be experienced in a context other than a purely mathematical one.

Teachers making skilled use of mathematical resources and working closely with parents, including sharing information about the mathematics curriculum are important means of reinforcing mathematical learning. In New Zealand many deaf/hearing-impaired children attend mainstream early childhood facilities/schools and this investigation has indicated the need for more teachers to be trained/experienced in working with deaf/hearing-impaired children.

In order for teachers to assist deaf/hearing-impaired children to achieve positive mathematical learning outcomes they must be fully conversant with both the mathematics curriculum (Ministry of Education, 1992) and *Te Whaariki* (Ministry of Education 1996). They will then have an in-depth knowledge of both children's mathematical thinking, and the requirements for creating holistic learning environments which facilitate mathematical learning. This knowledge, together with an insight into the specific learning styles and developmental needs of deaf/hearing-impaired children, will reduce the challenges that these children encounter in mathematical learning.

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