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Equal opportunities in mathematics: what does research on how young deaf children learn teach us?

Introduction

Nowadays, we face the challenge of preparing deaf children and youngsters to be as competent as their hearing peers in their adult life. To do this, deaf students should acquire new knowledge, learn new abilities, and solve new problems. It has been frequently pointed out that the society and economy of the XXI century will depend on workers competent in mathematics. In this context, educational aims should focus on helping deaf students become exceptional problem solvers, to reason, to make logical connections, to value this assignment and to earn confidence in their abilities to learn mathematics (National Council of Teachers of Mathematics, 1989, cited in Daniele, 1993). If deaf people are going to successfully participate in society, they should be provided with school experiences which adequately prepare them for such full participation. In more and more technologically advanced societies, which require increasing abilities on the part of its members, deaf people should be able to benefit from opportunities to develop problem solving strategies and abilities that are generalizable to employment and an independent life.

In this article a revision of research on mathematics in young deaf children will be made and will show what can be learned about some key considerations regarding teaching mathematics to deaf children, with the aim of achieving equal opportunities for deaf and hearing individuals.

The delay of deaf children in the area of mathematics

A substantial amount of research reported that deaf children are delayed by two or three years in learning mathematics with regard to their hearing peers (National Council of Teachers of the Deaf, 1957; Wollman, 1965, cited in Nunes and Moreno, 2002; Wood et al., 1983; Wood et al., 1984; Allen, 1995, cited in Pagliaro, 1998a; Traxler, 2000, cited in Pagliaro and Ansell, 2002).

Since the end of the fifties, researchers have reported failure in teaching mathematics to deaf children in the USA and Great Britain. In Spain, the situation may be worse due to its general context. A few years ago, a committee of national and foreign experts presented a report to Congress alerting about the low achievement of youngsters in sciences, especially mathematics, physics and chemistry. It pointed out that, "It is necessary that the teaching of these science subjects is reinforced, that the initial and permanent training of [school] teachers of these subjects is redesigned, that teaching time is augmented and that there is an overall increase in practical exercises in school laboratories, and that science is explored" (Jounal El País, 07/21/03). In the case of deaf people, Fernández-Viader points out that there are very few that have had success in their secondary studies and very few that have had access to the university level (MEC, 1996; Fernández-Viader, 1997c, 1999a, cited in Fernández-Viader, 2002). We can consider that in a basic school subject like mathematics, failure is not unusual for the deaf population.

Wood et al. (1983) studied if hearing loss as such was the cause of the delay but discarded this idea due to the fact that not every deaf child demonstrated more problems in solving standardized exams with regard to their peers. If deafness itself would be the cause of difficulties in mathematics, deaf children that have adequate achievement in mathematics considering their age level would not exist. However, approximately 15% of profoundly deaf pupils overachieve with regard to children in general.

In another study, Wood et al (1984) formulated the hypothesis that educational setting was the cause of difficulties in mathematics, due to the fact that special schools may prioritize teaching oral and written language over teaching this particular subject. They thought that mainstream schools with special units for deaf pupils received better attention regarding the teaching of mathematics. Nevertheless, from the obtained results, educational setting had to be discarded as a factor causing the detected difficulties. It was observed that deaf and hearing students did not differentiate in the type of errors committed and in the particular items they made mistakes on. Also, deaf children did not appear to be more impulsive than hearing children when solving the tasks.

Other researches have highlighted some factors that could contribute to deaf children's poor performance in mathematics. The most remarkable disadvantage is due to the fact that deaf children have fewer opportunities for incidental learning (Furth, 1966; Marschark, 1993). They have difficulties learning from certain incidental situations, from which hearing children obtain knowledge.

On the other hand, there are factors that are directly related to the formal education of deaf children, as the curriculum is frequently centred round calculations and basic abilities (Pagliaro, 1998b). Some studies report a deficit in the preparation of deaf teachers for teaching mathematical contents in a beneficial way to deaf students (Pagliaro & Ansell, 2002). According to this research, teachers often rely on repetitive paper and pencil exercises or computer sequences of exercises. In a study carried out in the USA with kindergarten to primary school teachers investigating the use of story problems in teaching mathematics to deaf children, it was found that teachers used story problems relatively infrequently. Less than 20% of the teachers indicated that they used them daily. Those who used them less frequent were teachers of the lower grades, as if they were waiting to use story problems once children have acquired the ability to use operations and number facts to solve them. Findings regarding frequency and mode of presentation of story problems showed that teachers followed an instructional pattern in which story problems were used as opportunities for the students to practise knowledge that was *already* acquired (Hiebert et al., 1996, cited in Pagliaro and Ansell, 2002).

Other factors related to oral language competence that make understanding of given mathematical tasks problematic, such as story problems, may be related to the difficulties deaf children have with reading comprehension (Serrano, 1995) or the use of words that have different meanings inside and outside of the classroom, as well as the possibility of expressing the same idea in different ways. This can cause difficulties for the deaf students for whom oral language is not their first language (Kidd et al., 1993).

Considering deafness as a risk factor in learning mathematics

Nunes and Moreno (1998a) suggest that hearing loss should not be considered a cause of the difficulties that deaf children have in learning mathematics but a risk factor for difficulties in learning mathematics. First of all, as we have previously outlined, not all deaf students are delayed in regards to their hearing peers (Wood et al., 1983). Secondly, most of the conducted research has not found – or has found a weak – correlation (Nunes and Moreno, 1998a; Wood et al., 1983) between hearing loss level and achievement in mathematics. The statement, *"the more hearing loss the worse the achievement level"*, does not apply. Next, the development of counting (Secada, 1984), calculation abilities (Hitch et al., 1983), and problem solving abilities (Nunes and Moreno, 1997, cited in Nunes and Moreno, 2002) seem to follow the same pattern as that of hearing children but at a slower pace. On the other hand, an explanation of a delay in terms of reading comprehension cannot justify poor performance on tasks that do not involve reading, as for example, conservation tasks.

To sum up, there is no a clear explanation of the cause of the delay in deaf children and youngsters in the area of mathematics. This is due to the fact that hearing loss has always been thought of as the cause of the delay. A cause is intrinsic to the learning process and would affect it – deaf and hearing children would qualitatively differ in the development of mathematical concepts. Conversely, a risk factor is external to the learning process and so, the number development process would be very similar in deaf and hearing children. The foundation for learning mathematical concepts is not language but the schemas of action, and because of this fact, the learning processes of deaf children would not differ qualitatively from those of hearing children.

Also, considering deafness as a risk factor means that the difficulties deaf children have in learning mathematics may be overcome by adapting teaching strategies to the learning capabilities of deaf children. As we will present in the following section, educators may help prevent the delay by adapting their teaching to a preferred way of processing information by deaf children and adjusting it to both overcome disadvantages as well as profit from the advantages that deaf children have in learning mathematics, as has been shown by recent studies (Zafarty et al., 2004).

The development of mathematical concepts in deaf and hearing children

Young hearing children (5 or 6 year olds) are able to think about situations that involve numbers and are able to solve a variety of simple problems. The majority of these children are able to use counting to solve easy problems of addition, subtraction, multiplication and division if they are able to represent these situations with concrete objects – they have schemas of actions, i.e. generalized ways to organize their actions to solve problems.

Two key difficulties of learning mathematics for young children are related to 1) learning the number system and 2) coordinating their schemas of action with concepts of mathematical operations.

With regard to the first subject, learning the decimal number system implies grasping the concept of place value. For example, for the number 12, it is necessary to understand that the 1 at the leftmost side means 10 units and that the 2 means 2 units. Children able to count to 12 may not be able to combine a coin of 10 cents with two 1 cent coins to make 12 cents. To do this they need to be aware that every value up till 10 is included in only one representation – the comprehension of counting based only on linear one to one correspondence is not enough. The ability to combine coins of different values is an indication that children understand *additive composition*, which means that they are aware that every number can be seen as the sum of other numbers (Nunes and Bryant, 1996). Comprehension of additive composition is a better specific predictor of understanding place value in our number system and the concepts of addition and subtraction (as assessed through problem solving). Acquiring the concept of additive composition is often facilitated in hearing children by knowledge derived from counting money. Deaf children are shown to be significantly behind hearing children in counting money (Nunes and Moreno, 1998). Counting money, an activity frequently learnt in informal experiences outside school, provides children with experiences that are more cognitively advanced than counting objects.

With regard to the second issue of coordinating children's schemas of action with concepts of mathematical operations, there are some aspects that should be taken into account:

Firstly, there is correspondence between a situation posed in a problem and the arithmetic operation that should be used to solve it. In some problems, there is clear correspondence between the situation and the arithmetic operation while in others there is not. For example, in the following problem, "Mary had some sweets; her mother gave her 5 and now she has 9. How many sweets did she have before?" the situation involves addition of sweets, but the operation that leads to solving the problem is subtraction.

This means that the child has to build various types of connections between schemas of action and arithmetic operations – direct connections are not enough. The process that leads to the development of these connections is social because the conditions of the arithmetic operations, defined during the course of history, are cultural and conventional. As communication is involved in learning these cultural concepts, deaf children are at a risk. Nevertheless, as stated earlier, the foundation of this type of learning is not language but schemas of action, and therefore, the processes of deaf children should not differ qualitatively from those of hearing children. Once they know the conventional aspects, the organization of their concepts should be very similar to that of hearing children, and predictors of their performance should be the same for both groups.

Deaf children show both disadvantages and advantages for learning certain important mathematical concepts. For example, learning the counting chain is difficult for deaf children (Nunes and Moreno, 1998a). Hearing parents of deaf children seem to put less emphasis on teaching the counting chain to them, and conversely, hearing parents of hearing children, as well as deaf parents of deaf children, normally dedicate more time to practise the counting chain. Nevertheless, once they have learnt it, they can use it as efficiently as hearing children (Secada, 1984). Moreover, as has been studied with signing deaf children, sign language allows deaf children to develop object counting abilities at least as good as those developed by hearing children on the basis of oral language (Leybaert and Van Cutsem, 2002).

Another detected difficulty that deaf children have is making inferences involving time sequences. The results of an intervention study (Nunes and Moreno, 2002) dealing with this subject show that teaching concepts at school that hearing children seem to acquire informally and using drawings and diagrams to support communication about time sequences, enhances deaf children's mathematical learning.

Deaf children also show some advantages with regard to hearing children, for example, better spatial processing in number representation tasks (Zafarty et al, 2004). The conclusions of a study carried out with 85 deaf children between the 2nd and 5th grade of primary school indicate that enabling deaf children to solve problems using drawings and visual mathematical tools meaningfully enhances their ability to solve problems using action schemas, compared to using materials that are normally used at school (Nunes and Moreno, 2002). Results are also consistent with the hypothesis that both deaf and hearing children develop number comprehension through schemas of action, which should be connected, later on, with formal representations at school. Both deaf and hearing children showed the same difficulties with different problem types. Problems with an unknown result were easier than problems with an unknown transformation, which in turn were easier than problems with an unknown beginning – which were the most difficult to solve for both deaf and hearing children. This shows that development with respect to solving addition and subtraction problems did not differ between deaf and hearing children. Studies on solving strategies in addition and subtraction show that deaf children use the same strategies as hearing children, with the exception of those strategies that include the use of sign language (Frostad, 1999).

Conclusions

Research of the last decades coincides on the fact that deaf children show a delay in learning mathematics with regard to their hearing peers, although it seems that both deaf and hearing children have the same mathematical development. Further analysis show that the cause of this delay is not clear. This supports the idea that a key aspect is the design of instructions that will help both deaf and hearing children create strong links between their own action schemas and the mathematical concepts they learn at school, and this applies to additive as well as multiplicative reasoning (Nunes et al., 2009).

The idea of conceptualizing deafness as a risk factor for difficulties in learning mathematics (Nunes and Moreno, 1998) opens the door for educators and psychologists to design instruction activities that will overcome these difficulties by taking into account preferred ways of communicating and processing information by deaf persons.

With regard to communication, we think an important aspect is teaching deaf children in a language that they have complete access to, i.e. sign language. It should be, however, considered that it should not be the only language at school but the vehicular language of instruction since communication problems cause deaf students to be delayed not only in mathematics but in every area of instruction.

With regard to information processing abilities, an overall conclusion is that mathematical tasks should be designed to match deaf children's information processing preferences – teaching strategies should be adapted to a visual way of processing information. Deaf young children are better than hearing children in processing information presented in a spatial modality (Zafarty et al., 2004). The use of visual mathematical tools implemented in exercises, such as the number line, graphs, and tables enhances deaf children's mathematical learning, both in addition and subtraction as well as in multiplication and division. Conversely, their difficulties in processing time sequences may be overcome with the use of drawings and diagrams to support sequential information present in story problems (Nunes and Moreno, 2002).

Another important conclusion is that problem solving should be used as a privileged way to *teach* mathematical concepts and not as a way to *apply* knowledge already acquired, both with deaf and hearing children. It is important that children have frequent opportunities to interact with various types of story problems, taking profit of their intuition and experience.

Of the presented experiences, we can extract other didactical recommendations, such as the importance of explicitly teaching certain important concepts that hearing children learn partly outside of school (what is called incidental learning) as, for example, the concept of additive composition. Other strategies include teaching concepts focused on various perspectives, using graphical representations of the given information, emphasizing teaching how to count, and of course, using story problems for teaching basic mathematical concepts.

With regard to the importance of teaching in an explicit way certain concepts that hearing children learn outside of school, it is recommended to teach deaf children certain notions about the decimal number system that constitute the base of number knowledge (Fuentes, 1999). Hearing children possess knowledge about the number system before explicitly being taught it. This knowledge is not enough to immediately use as a tool for communicating cardinality but constitutes the foundation of the formal properties of the decimal number system (Tolchinsky, 2003). Number notations are, in a distinct way, part of the children's surroundings before they begin formal schooling, and in an indirect way, through comments adults make about them. In the case of deaf children of hearing parents, communication about notations may be affected in a certain way, so concepts about notational media, which hearing children obtain in an incidental way, should be explicitly taught to deaf children.

According to the research we have synthesized, communication and didactical aspects seem to have a substantial amount of responsibility in the mathematical achievement of deaf children. With regard to teaching aspects, trained teachers of the deaf who are competent in their knowledge of mathematical contents, pedagogical strategies and *cognition*, i.e. how students acquire and process the contents, are the foundation. Another possibility is to have mathematics teachers that work with an interpreter in the classroom.

We want to add that conducting research about the development of teaching methods that are able to help deaf children enhance their achievement in this area, may also enhance the performance of children that suffer from a delay in mathematics, being either deaf or hearing.

Considering the problems of communicating school contents, we support the idea that schools should adapt to deaf persons, mainly through programs of bilingual education, "It seems obvious that, for deaf persons, access to education and culture is achieved when the educational response adapts to their needs. This response should recognise and respect their specific differences. For the deaf students, the difference is only the channel of access to information, and, as a consequence, to the school syllabus" (Fernández-Viader, 2002). Schools should adapt to the needs of deaf students and not the reverse, and this is a prerequisite for achieving equal opportunities for deaf students.

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Abstract

In this article we review research on teaching and learning mathematics by young deaf children. Research proves that deaf children show a delay in learning mathematics but reveals that the number development process should be very similar in deaf and hearing children. Previous and recent studies agree that the difficulties young children have in learning mathematics are linked to difficulties obtaining information in an incidental way from their environment. Considering deafness not as a cause but as a risk factor of difficulties in learning mathematics (Nunes and Moreno, 1998) opens a way of overcoming difficulties via adapting teaching strategies to the learning capabilities of deaf children. Research recommends taking advantage of deaf children's preferred ways of processing information and of their better spatial processing skills. The reviewed studies reveal a hopeful future regarding the achievement of equal opportunities for deaf and hearing persons in this important area of knowledge.

Równe szanse w matematyce: czego dowiadujemy się z badań dotyczących uczenia się dzieci głuchych?

Streszczenie

W niniejszym artykule dokonujemy przeglądu badań dotyczących nauczania–uczenia się matematyki młodszych dzieci głuchych. Badania dowodzą, że u dzieci głuchych widoczne jest opóźnienie w nauce matematyki, lecz proces rozwoju liczenia powinien być bardzo podobny u dzieci niesłyszących i słyszących. Analizowane badania zgodnie wskazują, że trudności w nauce matematyki związane są z trudnościami uzyskiwania przez małe dzieci informacji w sposób przypadkowy ze środowiska. Uznanie głuchoty nie za przyczynę, ale za czynnik ryzyka trudności w nauce matematyki (Nunes i Moreno, 1998) otwiera drogę do pokonania przeszkód poprzez dostosowanie strategii nauczania do możliwości uczenia się dzieci głuchych. Zaleca się wykorzystanie preferowanego przez dzieci głuche sposobu przetwarzania informacji oraz lepiej rozwiniętych umiejętności przetwarzania przestrzennego. Omówione badania ukazują jasną przyszłość w odniesieniu do wyrównania szans dla osób głuchych i słyszących w tej ważnej dziedzinie wiedzy.

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