Students with hearing impairment: Challenges facing the identification of mathematical giftedness

Swetlana Nordheimer, Matthias Brandl

Students with hearing impairment: Challenges facing the identification of mathematical giftedness

Swetlana Nordheimer[1] and Matthias Brandl[2]

1 Ellen-Key-Oberschule and Humboldt-University, Berlin, Germany, swetlana.nordheimer@gmail.com

2 University of Passau, Faculty of Computer Science and Mathematics, Passau, Germany, Matthias.Brandl@Uni-Passau.de

Usually a mixture of student's interest, qualitative teacher's observation and quantitative tests is used in order to identify mathematical giftedness. However, for children with hearing impairment, traditional ways of identification and diagnosis need to be adjusted, especially when it comes to quantitative aspects. The challenges of this process are illustrated by a case study and conclusions (like less time limits in tests, more visual helps) are drawn.

Keywords: Mathematical giftedness, hearing impairment, identification, inclusion.

INTRODUCTION

In 2008, the UN *Convention on the Rights of Persons with Disabilities* was ratified in consequence of *The Salamanca Statement and Framework for Action on Special Needs Education* in the context of the UNESCO *World Conference of Special Needs Education: Access and Quality* in 1994. The Convention aims at ensuring „an inclusive education system at all levels" (UNO, 2008, Article 24) which satisfies the needs of „*all children* regardless of their physical, intellectual, social, emotional, linguistic or other conditions. This should include disabled and gifted children" (UNESCO, 1994, 6). And therefore, the question of how to recognize and foster children that bring together two different specifics, i.e., *hearing impairment* and *mathematical giftedness*, is massively challenging and important.

The purpose of the study is to present a first exploration of the field and start the development of appropriate research questions with regard to the identification of mathematically gifted students with hearing disabilities. Further, we outline several complexities in the identification of gifted children with special needs that require future systematic research.

THEORETICAL BACKGROUND

The following paragraphs shortly summarise some facts from literature on the identification of mathematical giftedness, children with hearing impairment (hi) and the mathematical development of hi-children.

Identification of mathematical giftedness

According to Renzulli (1978), giftedness is characterised by *above average ability*, *high levels of task commitment*, and *high levels of creativity*. These aspects are acknowledged to be important for giftedness in mathematics education as well (Leikin, 2011). As already discussed in Brandl (2014), there are different ways of identifying and selecting promising students for reasons of fostering (in mathematics). One option is to rely on the students' own *interest* in mathematics as the main motivational force and most important factor for mathematical giftedness (see amongst many others Kruteskii, 1976). A second way is to trust in teachers' choices, adding a *qualitative* external selection component to the students' interest (see Linke & Steinhöfel, 1986, for example). A third option would focus on *quantitative* methods and result in testing the students (see Nolte, 2012; Kontoyianni et al., 2011, amongst many others). In general, identification processes often are designed as a combination of these three ways (see Wagner & Zimmermann, 1986, for example).

Children with hearing impairment (hi-children)

The term 'hearing impairment' comprises several cases: dysfunctions of the auditory system, hardness of hearing, deafness. It may be caused by genetic reasons, trauma or disease. However, the terms "deaf" (d) or "hard of hearing" (hh) which are accepted in their community of people, not only imply the degree, type or configuration of hearing impairment, but also the way of communication the person uses. Most of hh-people rely on residual hearing and communicate through speaking and lip-reading. In noisy environments, however, it can be very hard for them to communicate verbally. Thus, they are likely to face various difficulties at school and differ in their educational and psycho-social development from their hearing (h) classmates. An hh-person may use a hearing aid to perceive what is spoken around him or her. In case of severe impairment, the person may not be able to distinguish any sounds or spoken language, even with a hearing aid. The majority of d-people use sign language to communicate. The majority of the h-people neither use sign language, nor do they have an understanding of the special needs of hi-children. This is why hi-children often find themselves facing great challenges with regard to their language skills, potentially carrying away gaps in vocabulary and difficulties in articulation, for example. This is likely to have an impact on their cognitive and social-emotional development (Leonhard 2002, pp. 71ff.).

Mathematical development and giftedness of hi-children

Pagliaro and Kritzer (2012, p. 139) summarise the results of current studies and conclude: "Consistently, over decades and across grade levels, deaf/hard-of-hearing (d/hh) students in various countries have scored poorly on mathematics assessments." The authors try to explain this "math gap" of d- and hh-children by the limited experiences and lack of ability to learn mathematical concepts, e. g. numbers by incidence, because of the language barriers separating them from their natural environment. Gregory (1998, p. 122) names two other possible reasons for the difficulties especially of d-children to cope with mathematical tests and assessments: the nature of specialized mathematical language and the suppression of sign language in mathematical education. Because of this reduction, mathematical signs cannot be developed in an appropriate way.

Further reasons for the differences in the development of mathematical thinking can be found in the specifics and obstacles within communication processes between hi- and h-people. Solving mathematical word (and modelling) problems usually starts with reading and understanding written texts. These texts often contain short words (e.g., prepositions), which are underemphasized in spoken language and can easily be overheard (or overseen by hi-students, when relying on lip-reading or sign-language). Moreover, there are specific mathematical terms like "product" or "root" which have different meanings in the common spoken language. This proves to be difficult to express in sign-language or figure out by lip-reading.

Engel (2000, p. 17) reports that many hi-children develop strategies in order to solve word problems without entirely understanding the text. These children try to simplify and restructure the text. This process can be compared with the reading of fill-in-the-blank texts. In some cases, these strategies are successful, in many others they are not. Cohors-Fresenborg (1988, pp. 102ff.) claims that hi-children excelled in solving problems, which had been represented visually or haptically without using written or spoken language. These children achieved particularly high scores, when it came to problems which demanded high modelling competences (reconstruction and reorganization). Biographies of famous deaf mathematicians and scientists also show that hi-people can be brilliant problem solvers or gifted mathematicians (confer Lang & Meath-Lang, 1995, p. 407). Obviously, not every hi-person is a mathematical genius, and the same applies to h-people. There are, however, hi-students who are very interested and gifted in mathematics, and eager to solve mathematical problems. As for the discussed language difficulties of hi-students, it is not easy to recognise their mathematical giftedness, because most diagnostic instruments use spoken or written language to represent mathematical problems.

Giftedness of children with special needs can be masked by their disability. Gifted children with disabilities also often use their intelligence to compensate for their impairment. That is why it could be very difficult to recognise special needs of gifted children (Krochak, 2007; Nielson, 2002). Children whose hearing is impaired cannot respond to oral directions in the same way hearing children do, and they may also lack the vocabulary expressing the complexity of their ideas. They sometimes cannot respond to tests requiring verbal responses (Whitmore & Maker, 1985). Since the population of gifted students with special needs is difficult to locate, they are seldom represented in standardised test norming groups. This makes every comparison highly problematic. Pedagogical literature related to gifted hi-students lists criteria which should help to recognise giftedness, i.e., *Excellent memory, Rapid grasp of ideas, High reasoning ability, Superior performance in school, Wide range of interests, Nontraditional ways of getting information, Use of problem-solving skills in everyday situations, Delays in concept attainment, Self-motivation, Ingenuity in solving problems, Symbolic language abilities like different symbol system* (Cline & Schwarz, 1999; Whitmore & Maker, 1985).

METHOD

In order to illustrate aspects of the diagnostic challenge, a single case study was done.

Description of the student

The study deals with Leon[1], who is now visiting a 5th grade at the special school for hi-children in Berlin, where pupils are grouped in small classes of ten. The classrooms are equipped with technical aids and visual materials in order to support spatial thinking, and, compared to conventional schools for h-children, students get more time to work on their assessments. At the beginning of the study in August 2012, Leon was still a 3rd grader. According to the pupil's record, Leon suffers from bilateral[2] sensorineural[3] severe hearing loss of 60 to 70 dB. Leon is hard of hearing since he was born. Since his first year he has been using hearing aids, but it is still difficult for Leon to perceive spoken language without being able to watch the lips of his communication partners. Leon's parents and all his siblings are hearing and use oral language to communicate. It was not until he started school, that Leon was confronted with sign language. After one year, his parents decided to invest in one-to-one-language therapy. Because of Leon's special needs with regard to language, his parents finally sent him to the special school for hi-children.

At the beginning of 3rd grade, Leon had difficulties to express himself and to articulate his thoughts. Misunderstandings and conflicts with his classmates or even teachers were frequent and usually ended up in tears. Probably in order to avoid these situations, Leon very often waived explanations of his needs and feelings. Still, even more remarkable than Leon's communicational obstacles was and is his tremendous motivation to do mathematics. According to an interview done with his former mathematics teacher, he attracted her attention during the mathematics lessons through his eagerness to solve mathematical problems and his endurance when working on difficult and new tasks. According to his educational file, Leon discovered multiplication on his own by working with Montessori materials for preschoolers in kindergarten, when he was four years old.

At school, he works in mathematics classes with concentration, listens to the teacher and his classmates very carefully and examines what they said mathematically. He always manages to complete more mathematical tasks and problems than his classmates and sometimes poses his own questions and problems to the teacher as well. The tasks Leon tried to avoid in 3rd grade were word problems. Usually, his mood changed as soon as he was presented with a word problem. He often did not even start working on it, unless his teacher encouraged him strongly. Then he asked for the meaning of some words and tried to solve the problem, but he was not always successful, mainly because of textual misunderstandings and mismatches between the world of mathematics and the world of written German language.

Despite his difficulties, the mathematics teacher who taught him in 1st and 2nd grade recommended Leon for "Mathe-Treff" at Humboldt University in Berlin. This is a program for gifted students from primary schools from all over the city. The "little mathematicians" meet once a week for one and a half hour to solve mathematical puzzles and problems. They are assisted and observed by students of the educational department and the leader of the project, Prof. Marianne Grassmann. The biggest part of mathematical puzzles and problems is verbalized in written German language, so this represented a real big challenge for Leon. For this reason, two students from the department for special education were supporting Leon. They adapted mathematical word problems to his communication level and offered their help. Not all children managed to participate till the very end of the course, because it was not easy to stay motivated to do mathematics after a long school day. However, Leon was among those who completed the whole one-semester course successfully.

Identification method for mathematical giftedness

In Leon's case the decisive factor for the identification of mathematical giftedness was the teacher's recommendation. As mentioned earlier, the careful observation of the child during class can be a successful qualitative method. A very important part of this observation method was the study of the child's written products. We examined number tasks and word problems, both done within regular mathematics lessons. These observations were accompanied by a quantitative extracurricular assessment, intelligence and development test: In order to compare Leon with his hearing peers and to see his mathematical giftedness within the context of his general development, the IDS (Intelligence and Development Scales) for five- to ten-year-old children was used as a further diagnostic instrument (Grob et al., 2009). IDS was invented to provide differentiated insight into intelligence and general development in areas like Cognition, Psycho-Motorics, Social-emotional Competence, Mathematics, Language and Achievement Motivation at the beginning of the school career. It focuses on the dynamics of so-called individual "strengths" and "weaknesses" and puts them in relation to the child's development profile and to his corresponding peer-group. The test consists of different modules[4] and can be used as a whole or in parts. Except for the modules Phonological Memory and Auditive Long-Term Memory, it is possible to pose and solve the test tasks without spoken language. More language instruction is necessary when it comes to the modules describing General Development.

IDS was chosen as a diagnostic instrument, because it allows for comparison of Leon's intellectual abilities with the average population. It provides for precise and distinctive insights into different areas of the intellectual and social development and shows the interaction of talents and special needs. It could help to avoid that intellectual abilities and language needs collide. In this sense it could provide insights into the ability to compensate for hearing and language problems. Besides, the part *Achievement Motivation* of the IDS allows for conclusions about task commitment, which according to Renzulli (1978) can serve as an important characteristic of mathematical giftedness. It is difficult to make conclusions about mathematical creativity using IDS as a quantitative instrument, since the answers are standardised. That is why Leon was asked to talk about IDS-items and to explain his solutions, which were written down and then used as questions for qualitative interviews.

Since time was very limited, Leon was not exposed to the whole test. Instead, a selection of *Intelligence*, *Social-emotional Competence*, *Mathematical Competence*, *Expressive Language Competence* and *Achievement Motivation* was chosen. When taking the test Leon was 9 years and 7 months old. The test was completed in a one-on-one situation.

RESULTS

We illustrate how written products can indicate mathematical giftedness by describing and analysing some chosen cuttings from Leon's booklet and items of the IDS test.

Number tasks (regular lessons)

Leon's answer to the question: "Draw your favourite number." was the number 201031 which has six digits. Leon also knows that 200000 + 1000 + 31 = 201031. At this moment most children in the classroom were expected to deal with numbers under 1000. Some of them painted numbers above 2000 but not above 3000.

When it came to the figurative representation of numbers with three digits, Leon invented his own notation. The task for "Zahlenbild" was to find a symbolizing picture for numbers. (Example: the number is 300. Intended and trained solution: □□□). In contrast to other children he did not draw three squares in order to represent for example three hundred as a sum, but he used a multiplication sign to shorten the notation (□x3). So, Leon's solution does not confine itself to non-mathematical (purely additive) pictograms but extends it by bringing in abbreviating mathematical symbols.

Some months later the students learned how to add numbers under 1000 via an algorithm. Leon did not only use this algorithm to solve several given problems without a single mistake, but invented his own problems with bigger numbers and looked for new regularities.

Word problems (regular lessons)

Compared to a regular school, at the special school for hi-children mathematical word-problems are usually verbalized clearer and the numbers in it are kept small in order to make it easier for the students to solve them. Further, text problems have been translated into visual representations or supported by other special tools like small blocks and Montessori-materials. Students could use stamps to solve the problems or to control their results. The problems were offered at three difficulty levels. Leon chose the easiest problem first and controlled his result with stamps. In a second step he applied his solution to a more difficult problem dealing with spiders. Since he had understood the structure of the first problem, he was now able to transfer it onto the text structure of the spider-problem without using stamps as visual aids. Remarkably, Leon found it important to notice the commutativity of the multiplication.

Assessment, Intelligence and Development test IDS 5–10 (extracurricular)

Leon's intellectual performance with IQ = 109 lies according to the IDS in the upper average area in relation to his hearing peers. In the sub-test Selective Attention Leon achieved the highest possible score [Value Points (VP) = 19]. The scores in the sub-tests Auditive Long-Term Memory and Conceptual Thinking are above the average [VP = 14]. The other scores lay within the standard norm of his peers [VP = 9, 11, 12, 12]. It is remarkable, that Leon could manage all tasks of the sub-tests in Figural Thinking almost within the standardized time limits.[5] Leon's answers in the sub-test Social-emotional Development show that he can perceive and recognize other people's emotions within average norm [VP = 9]. Likewise, Leon is able to regulate his emotions [VP = 14] and understand social situations [VP = 13] better than most of his peers. However, he showed heavy deficits with regard to the aspect Social Acting [VP = 6]. In the sub-test Achievement Motivation Leon again reached the highest possible score. Leon's score in the sub-test Expressive Language lay way below the average norm [VP = 2]. He was able to express his thoughts, but he could hardly do it in the grammatically correct way as it was expected in the standard test. Some of his sentences are difficult to understand. However, if the sentences containing semantic and grammatical errors counted as correct, Leon would have reached VP = 12, which corresponds to the average. Within limited time he attained VP = 14 in the sub-test Mathematics, which is above the average. Without time-limitation Leon managed to solve all mathematical problems except one word problem and reached VP = 19, which is far above the average compared to children of his age. In order to gain deeper insight into Leon's mathematical thinking we will discuss some items of the test closer.

There were two very similar word problems which were read out loud to the children. The respective tested child was given toys (small doll, cat, dog and cups) to illustrate the solution and was expected to explain it. Leon managed to solve one problem and was not successful with the other. The reason was that the chosen vocabulary and the text structure of the unsolved problem were more complicated than in the problem Leon could solve. Other problems were verbalized as well, but they could be solved almost without understanding the text. The information needed was also represented by visuals or symbols. Leon soon ignored the text and solved them only by using mathematical symbols. In the second task he had to deal with numbers which, by that time, were no subject matter of the mathematics curriculum: „A counter is counting people, who are coming into the stadium. The counter shows this number. What would the counter show, if 201 more people would come to the stadium? Write the numbers into the nearby blanks" (Figure 1 left). Leon solved the problem and even put a point into the number. This demonstrates, that he understood the meaning of the written symbols. The next two problems referred to Geometry: "How many cubes are in this figure? Fill in" (Figure 1 bottom). In these tasks Leon showed his good abilities in figural and spatial thinking.

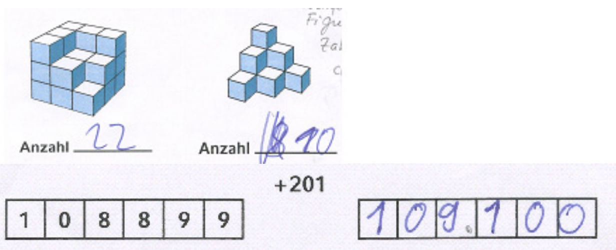

Figure 1: IDS/Items 14 to 16

The final problems checked his orientation in the range of numbers 0 to 100000. Since Leon had until then only learned numbers under 10000, he found himself working with new numbers and still managed to find the correct solutions in the given time. He could not solve the very last problem in the given time, but he found out the right numbers after the time was over. This appears even more remarkable, since he transferred his knowledge about numbers under 10000 to numbers over 10000 (Figure 2 bottom).

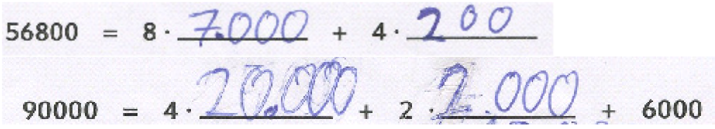

Figure 2: IDS/Item 17 & 18

CONCLUSION

Language barriers essentially complicate the identification of mathematically gifted hi-children. However, the documents presented in the results section clearly show that a hi-child like Leon can also develop the ability to analyse the structure of numbers, to play with them, to invent an own notation, to work with different modes of representation and to compensate for his language difficulties by visual help (for example stamps) or mathematical signs (multiplication sign). Although these results were achieved in the setting of a special school, the case study of Leon can inspire appropriate combinations of qualitative and quantitative methods that can work out successfully in regular (inclusive) schools, too: documents and products from student observations combined with standardised tests (perhaps including less time limits and more visual helps) may overcome language barriers and lead to differentiated insights into the child's possibilities. In the end, this could be of great help not only in order to predict a hi-student's success in programs for gifted children, but also in order to provide him with the individual support needed.

The results of the study correspond with criteria for mathematically gifted hi-children and the study leads to the following future research questions: What kind of information about mathematical giftedness of children with hearing difficulties allows for a quantitative comparison with children without hearing difficulties? Does it mean that hi-students with the same score as hearing students have greater competence, given the knowledge that they compensate for their disadvantages? In what way need criteria for mathematically giftedness to be altered in order to address students with hearing problems? How can this information help to predict hi-students' success in programmes for fostering mathematical giftedness that are usually designed for hearing students?

REFERENCES

Bess, F.H., Dodd-Murphy., J., & Parker, R.A. (1988). Children with minimal sensorineural hearing loss: Prevalence, educational performance, and functional status. *Ear and Hearing, 19*(5), 339–354.

Brandl, M. (2014). Students' picture of and comparative attitude towards mathematics in different settings of fostering. In B. Ubuz, Ç. Haser, & M.A. Mariotti (Eds.), *CERME8 – Proceedings of the Eighth Congress of the European Society for Research in Mathematics Education* (pp. 1156–1165). Ankara: Middle East Technical University.

Cline, S., & Schwartz, D. (1999). *Diverse populations of gifted children.* NJ: Merrill.

Cohors-Fresenborg, E. (1988). Schulversuch: Algorithmisches Denken im Mathematikunterricht mit Hörgeschädigten. In *Beiträge zum Mathematikunterricht* (pp. 102–105). Bad Salzdetfurth: Franzbecker.

Engel, D. (2000). *Mathematische Fähigkeiten bei gehörlosen SchülerInnen. Eine Untersuchung im Rahmen der Begleitforschung zum bilingualen Schulversuch* (Wiss. Hausarbeit zur Prüfung für das Lehramt an Sonderschulen). Universität Hamburg, Fachbereich Erziehungswissenschaft, Institut für Sonderpädagogik.

Grob, A., Meyer, C.S., & Hagmann-von Arx, P. (2009). *Intelligence and Development Scales (IDS). Intelligenz- und Entwicklungsskalen für Kinder von 5–10 Jahren.* Bern: Verlag Hans Huber.

Gut, J., Reimann, G., & Grob, A. (2013). A contextualized view on long-term predictors of academic performance. *Journal of Educational Psychology, 105,* 436–443.

Gregory, S. (1998). Deaf Children. In S. Gregory, P. Knight, W. McCracken, S. Powers, & L. Watson (Eds.), *Issues in Deaf Education* (pp. 119–126). London: David Fulton.

Kontoyianni, K., Kattou, M., Pitta-Pantazi, D., & Christou, C. (2011). Unravelling Mathematical Giftedness. In M. Pytlak, E. Swoboda, & T. Rowland (Eds.), *CERME7 – Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education* (pp. 1066–1074). Rzeszów: University of Rzeszów.

Krochak, L. A., & Ryan, T. G. (2007). The challenge of identifying gifted/learning disabled students. *International Journal of Special Education*, *22*(3), 44–53.

Kruteskii, V.A. (1976). *The Psychology of Mathematical Abilities in Schoolchildren*. Chicago, London: University of Chicago Press.

Lang, H.G., & Meath-Lang, B. (1995). *A Bibliographical Dictionary. Deaf Persons in Art and Sciences*. London: Greenwood Pub Group.

Leikin, R. (2011). The education of mathematically gifted students: Some complexities and questions. *TMME*, *8*(1&2), 167–188.

Leonhardt, A. (2002). *Einführung in die Hörgeschädigtenpädagogik*. München, Basel: Reinhardt.

Linke, H. P., & Steinhöfel, W. (1986). Aspekte einer tätigkeitsbezogenen Begabungserkennung und einige Anregung zur Gestaltung der Zusammenarbeit der Erziehungsträger in diesem Prozess. In G. Meyer (Ed.), *Begabungsforschung* (pp. 40–51). Berlin: APW.

Nielson, M. E. (2002). Gifted students with learning disabilities: Recommendations for identification and programming. *Exceptionality*, *10*(2), 93–111.

Nolte, M. (2012). "High IQ and high mathematical talent!" Results from nine years talent search in the PRIMA-project Hamburg. In *ICME-12 Pre-proceedings* (pp. 1503–1512). Retrieved from http://www.icme12.org/upload/upfile2/tsg/0696.pdf

Pagliaro, C. M., & Kritzer, K. L. (2013). The Math Gap: A Description of the Mathematics Performance of Preschool-aged Deaf/Hard-of-Hearing Children. *Journal of Deaf Studies and Deaf Education, 18*(2), 139–160.

Renzulli, J. (1978). What Makes Giftedness? Reexamining a Definition. *Phi Delta Kappan, 60*(3), 180–184, 261.

Shemesh, R. (2010). Hearing Impairment: Definitions, Assessment and Management. In J.H. Stone, & M. Blouin (Eds.), *International Encyclopaedia of Rehabilitation*. Retrieved from http://cirrie.buffalo.edu/encyclopedia/en/article/272/

Wagner, H., & Zimmermann, B. (1986). Identification and fostering of mathematically gifted students. *Educational Studies in Mathematics*, *17*, 243–259.

Whitmore, J. R., & Maker, C. J. (1985). *Intellectual giftedness in disabled persons.* Rockville, MD: Aspen.

ENDNOTES

1. "Leon" is a pseudonym because of protection of privacy. The child's real name is known to the authors.

2. in both ears

3. caused because of dysfunction of the inner ear

4. Visual Perception, Selective Attention, Phonological Working Memory, Spatial Working Memory, Auditive Long-Term Memory, Conceptual Thinking and Figural Thinking build General Intelligence.

5. Results which were scored without time limitation were not considered by the calculation of the IQ, but they still show that Leon could achieve more if he has more time and that he is able to concentrate as long as it takes him to get the correct solution.