


Making Mathematics Accessible to Visually Impaired High School Learners in South Africa: Teachers' Instructional Approaches, Assistive Devices and Challenges

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ABSTRACT

This case study explored the instructional approaches and assistive devices employed by high school mathematics teachers in teaching visually impaired (VI) learners and the challenges encountered by the teachers in facilitating the learners' construction of mathematical knowledge. The participants were two high school mathematics teachers from a special school for the visually impaired in South Africa. Data was collected via semi-structured interviews and lesson observation. Inadequate skills in using Braille codes, time constraints, lack of learners' home support structure, and technology failure are some of the challenges encountered by the teachers in teaching the VI learners. The approaches used by the teachers to teach mathematics to the VI learners in this study are direct instruction, contextual linking, scaffolding, peer tutoring, and problem-solving. The technologies the teachers used included text enlargers, text translators, text embossers, structure embossers, and scientific talking calculators. The study recommends in-service training for teachers teaching mathematics to

KEYWORDS

Assistive devices; blind learners; special-needs education; visually impaired learners

Introduction

Traditionally, mathematics has been largely inaccessible to visually impaired (VI) learners, not because they are less able to master the subject matter, but because access to abstract and visually presented material is not facilitated for them in the classroom (Baker & Haak, 2004; Brawand & Johnson, 2016). Several studies (Buhagiar & Tanti, 2011; Maguvhe, 2015; Rule et al., 2011) have indicated that VI learners have the same cognitive ability levels as their sighted counterparts and therefore can indeed learn the same mathematics content as sighted learners. Interestingly, Jackson (2002) found that mathematical knowledge involves the ability to create mental representations, which is inborn and does not depend on sight. According to Sedaghatjou (2018), understanding mathematical concepts can be established without the use of the sense of sight; other senses such as audio and touch can be developed and used. In research conducted by Arslan and Kayhan Altay (2021), spatial strategies used by VI students were found to be similar to those used by students without any visual impairments.

Spatial thinking and numerical reasoning are so closely linked that spatial skills or the lack thereof can predict learner performance and even career choices (Möhring et al., 2018). In addition, Kell et al. (2013) found that spatial skills also predicted the effective use of pre-existing knowledge and the conception and assimilation of new knowledge. In particular, spatial scaling, referred to by Möhring et al as 'the ability to relate distances in one space to distances in another space' (Möhring et al., 2018, p. 57), is a significant role-player in the development of mathematical prowess, and therefore also in the success of VI mathematics learners. In fact, Szubielska et al. (2019) found that the lack of visual experience impeded spatial-scaling abilities in congenitally blind individuals, such as the learners in this study.

Nevertheless, despite the potential of many VI learners to learn mathematics, there are serious challenges that are faced by both these learners and their teachers. Mugo (2013) conducted a comparative study on the rate of transmission of knowledge through visual, tactile and audio cues among learners, which indicated that learners' grasp of information is faster through the visual modality than it is through auditory and tactile modalities. However, while sighted learners can scan through texts, tables, charts and diagrams at a glance to obtain a general overview of the information, VI learners are unlikely to grasp or comprehend such abstract and illustrated information at a glance because of the nature of Braille. At the same time, the auditory and tactile senses, which are the channel of learning for VI learners, are much slower than sight because reading mathematics with fingers involves touching one-character detail at a time in comparison to getting general ideas at once by seeing (Mugo, 2015). Inevitably, the strategies through which VI learners learn mathematics are not quite the same as those of the sighted learners (Bayram, 2014). The kind of skills that are necessary to carry out the necessary strategy adaptations are not routinely taught in teacher training programmes (Maguvhe, 2015).

Szubielska (2018) found that three conditions need to be met in order for a VI student to succeed in mathematical subjects: the student needs to be worked with individually, didactic materials need to be adapted and specialised software needs to be available. Additionally, in a Southern African study, Madungwe (2018) found that the mathematics teachers of VI learners lacked specialist training, used the same teaching methods as those used with sighted learners, that little ground was covered in terms of the curriculum and that schools were not adequately resourced to assist the VI learners. The implication is that many opportunities to learn mathematics at secondary level are lost.

In South Africa, 'mathematics is expected to integrate a critical, democratic and mathematical competence such that citizenry participates meaningfully in the growing economy' (Jojo, 2019, p. 129). The same expectation applies to mathematics being taught to VI learners. According to the South African Mathematics Foundation, the approximate numbers of learners who wrote Grade 12 Mathematics in 2014 is 225 456, but statistics are not available as to how many of those were VI learners. However, the overall performance of VI learners in secondary school mathematics, is poor. As stated unequivocally by Morelle and Tabane (2019), South Africa is still 'struggling' to provide equal opportunities for learners with disabilities. In fact, many special schools for visually impaired learners do not offer mathematics in the Further Education and Training (FET) phase (Grades 10–12) (Fish-Hodgson & Khumalo, 2015). Out of 22 schools registered for visually impaired learners in South Africa, only two offer mathematics to VI learners in the FET phase (Maguvhe, 2015). Data supplied by the National Council for the Blind indicate that there

were 182 VI learners enrolled for Grade 12 in 2022, but there is no indication of how many of these students take mathematics as a subject.

As the literature indicates, the challenges are not confined to South Africa. For example, in Slovakia mathematics is not offered at all to VI learners in the special schools that have been provided; a VI learner who wishes to study mathematics has to attend a mainstream school where mathematics is offered (Kohanova, 2010). In Malta, according to Buhagiar and Tanti (2011), mathematics is not offered to VI learners because neither the education system per se nor the teachers are prepared or equipped for this. Similarly, in Turkey, although mathematics is offered to VI learners in inclusive schools, mathematics teachers lack the training and experience to teach mathematics to VI learners (Bayram, 2014).

This study explored the challenges experienced by secondary school mathematics teachers of VI students, and the techniques and technologies they employed in a South African school. The study addressed the following questions: (i) what instructional approaches do the mathematics teachers use to help VI learners construct mathematics knowledge? (ii) What assistive devices are used by mathematics teachers to enhance the acquisition of mathematics knowledge by VI secondary school learners and how are these deployed? And (iii) what are the challenges experienced by mathematics teachers in teaching mathematics to VI secondary school learners?

The VI Classroom: Approaches, Devices and Challenges

Instructional Approaches for Teaching VI Learners

One of the findings in the research of Spindler (2006), Brawand and Johnson (2016), Rule et al. (2011), Hassan and Salleh (2017), Szubielska (2018) and Sedaghatjou (2018) is that the instructional approaches generally used to teach VI learners do not differ significantly from those used to teach sighted learners in mainstream schools. This implies that the required adaptation and modification of teaching approaches and the curriculum itself do not take place, leaving mathematics generally inaccessible to the VI learner. In addition, it is important that mathematics problems are carefully and precisely described in a manner that is understandable to the learners while teaching (Spindler, 2006).

The literature in this regard describes possible adapted approaches that can be employed in teaching mathematics to VI learners. For example, Hassan and Salleh (2017) suggest contextual, collaborative learning, scaffolding, and focused direct-instruction approaches. Rule et al. (2011) ranked the contextual approach as the most effective approach to teaching VI learners since this approach allows the VI learner to construct meaningful knowledge from prior ideas leading to ownership of the new knowledge. Louw (2015) suggests that mathematics teachers use examples from the immediate environment that are familiar to the learners, as it is difficult for the VI learner to make connections by themselves despite the cognitive spatial skills that they may have. In view of the finding by Kell et al. (2013) that spatial skills are linkable to the effective use of pre-existing knowledge and the creation of new knowledge, the importance of mathematics teachers of VI learners using relevant pre-existing knowledge such as familiar contextual examples, is highlighted. Such examples, according to Stone et al. (2019), should be those that are readily accessible to the VI learner and linked as closely as

possible to their own lived experience. This implies that the teacher should not just be familiar with the mathematical content to be taught, but with the contexts with which the learners are familiar and within which they live. In the collaborative learning approach, the sighted peers work with VI learners. The sighted learners help to verbalise the component of mathematics problems as they learn the concept together. Similarly, Stone et al. (2019) noted that approaching mathematics through direct instruction could be effective as it allows the teacher to pace the lesson according to the ability of the learner and at the same time monitor students' understanding of key concepts and skills. Gersten et al. (2009) argue that learners benefit from being assisted individually through scaffolding. Noriega and Zambrano (2011) add that when the scaffolding approach is used appropriately, learners are made to understand the concepts easily as the teacher splits the concepts beforehand into smaller parts that the learners can manage progressively. Clearly, research is available to assist in teaching VI learners, but during the course of this study it became obvious that the teachers were not adequately equipped with knowledge regarding these strategies or how to implement them effectively.

Assistive Devices for Teaching VI Learners

These devices are customised to improve the functional ability of the VI learner and to increase their understanding of abstract mathematics content (Daroni et al., 2018). According to Mugo (2013), technology allows VI learners to think critically, as well as eliminating their barriers to learning. DePountis et al. (2015) noted that assistive technology tools, if effectively integrated into the learning of mathematics, can reduce the tediousness of chains of mathematical calculation, allowing the learner to pay more attention to conceptual development. Over the years various technologies have been employed to facilitate the learning of VI students. Perkins Brailers, Braille books, talking calculators such as the OrionTI-84, black line, and magnifying tools are some of the technologies identified by Bitter (2013) for teaching VI learners. In recent times, with the developments in computer technology, specialised computer hardware, and software like the Duxbury Braille translator speech output software, Braille embossers; iPad; print magnification devices; and screen readers have been developed and used to teach VI learners (DePountis et al., 2015; Oira, 2016).

Many of these assistive devices depend on the sensory capabilities of touch (Daroni et al., 2018). Those essential to teaching and learning in secondary schools include refreshable Braille display, note-takers, large screen devices, smart Brailers, audiobooks, smartphones, and computers. Oira (2016) observed that with the introduction of computer technologies VI learners are able to access mathematics independently through auditory and enlarged text.

Teachers' Challenges in Teaching VI Learners

A major challenge for the teachers in teaching mathematics to VI students is their own lack of skills and knowledge in teaching the learners. Many of the teachers who teach VI learners have not been sufficiently trained, if at all, to deal with the challenges inherent in teaching VI learners (Bayram, 2014; Donohue & Bornman, 2015). Fraser and Maguvhe (2008) observed that most mathematics educators in inclusive as well as in special needs

schools which cater to learners with visual impairments do not have qualifications which include training in the specifics of teaching in the VI classroom.

According to Kapperman et al. (1997) teachers teaching mathematics to VI learners are expected to introduce new mathematics Braille codes that are relevant to the learning content. This means that precise and correct mathematics codes should be introduced in all mathematics learning opportunities. However, most of the teachers do not know the mathematics Braille codes. Fish-Hodgson and Khumalo (2015) reported that there was a total of 123 teachers in the 22 public registered special needs schools in South Africa who did not know Braille.

The other significant challenge is the lack of technological resources. Inadequate assistive technology and teaching materials in an institution for VI learners is not a recent phenomenon (Mugo, 2013). Research has revealed that in most South African special needs schools for VI learners, teachers are unable to help learners construct mathematical knowledge due to limited resources (Maguvhe, 2015). These resources include all teaching/learning materials such as Braille books, computers, and computer programs.

Theoretical Framework

Teaching mathematics to VI learners depends on the skills that teachers have in adapting the curriculum content and using appropriate instructional approaches with assistive devices to help learners construct knowledge. Teachers are thus viewed as pivotal in the learning experience. This study is underpinned by the theory of constructivism, in which learning is predicated on two concepts: learning is a phenomenon where learners participate actively in the acquisition of knowledge, and knowledge is socially and culturally constructed within a context (Ekpenyong & Edokpolor, 2016).

A Constructivist's View of Teaching Mathematics

Traditional approaches to teaching mathematics were focused on direct transmission. The constructivist stance shifts learners from being passive receivers of knowledge to the learners who construct their knowledge and are actively involved in their learning. This paradigm shift has caused mathematics teachers to redefine their position to being facilitators who tutor, stimulate, and assist learners in constructing mathematics knowledge (Bada, 2015). According to Bozkurt (2017), effective facilitation of learning is achieved when teaching is contextualised so that the content is made meaningful to the learner. This means the concepts to be taught are situated within the natural environment with which learners are familiar. According to Prideaux (2007), when learners relate mathematical ideas to life experiences, they assimilate the new content with prior knowledge, constructing new knowledge.

A Constructivist View of Teaching Mathematics to VI Learners

From a constructivist perspective, the VI learners should be constructing mathematics concepts by actively participating in mathematics activities, as would in fact be the case with sighted learners. The tactile activities that VI learners engage in when learning allow them to be active and not passive learners under the guidance of a trained teacher who

can help them to use effective strategies for exploring by touch. According to Sedaghatjou (2018), when VI learners manipulate an object in their environment, they deliberately move their fingers to explore the object with a goal in mind. For example, a VI learner may touch a cylinder to experience the surface area. They deliberately feel the whole surface. Manipulatives help both sighted and VI learners make connections between concepts and the concrete object. In active learning, learners use their intellectual skills such as researching, metacognitive thinking, and critical skills knowledge (Cirik et al., 2015). This means that they, just like their sighted counterparts, can employ a problem-solving approach to construct knowledge by breaking up the problem into manageable steps as they work through the problem. In effect, they apply Polya's (1945) process for problem-solving.

The constructivist mathematics teacher strives to increase learners' participation in the activities in the VI classroom and to motivate them to learn through the scaffolding and peer tutoring approaches. The teacher, or a more knowledgeable peer, guides the VI learner by giving clarity on concepts that cannot be understood without assistance. According to Maguvhe (2015), the specialist teacher needs to articulate the subject matter to the VI learners which, in a constructivist VI classroom may involve modelling the problem to the individual learner or the group and then allowing the learner to practice. In this regard, Kohanova (2010) speaks of the VI learners producing their own knowledge 'as a personal response to the didactical milieu' (p. 5).

Research Method

This qualitative study was designed as a case study to capture the approaches, assistive technologies, and challenges of two mathematics teachers of VI learners at a secondary school for VI learners in South Africa. This school is one of two special schools for blind and partially sighted learners in South Africa that offers mathematics up to the Further Education and Training (FET) phase (Grades 10–12). The classes in this school are limited to an average of 20 learners, all of whom are visually impaired, ranging from partially sighted to blind. Two classes were surveyed: one Grade 9 and one Grade 10 mathematics class. The learners in these classes ranged between 15 and 17 years of age. They had no disabilities other than visual impairment.

The school has two Grade 9 classes and one Grade 10 class for mathematics. The Grade 10 class had eight learners, six of whom were partially sighted and made use of enlarged text material in their learning, while the other two learners were profoundly blind and used braille. The Grade 9A class also consisted of eight learners, six partially sighted and two with total blindness. The Grade 10 class was taught by teacher 1 and the grade 9 class by Teacher 2.

The focus of the observation was to investigate the teaching approaches used to teach mathematics to these VI learners, assistive devices utilised in the classroom, and challenges experienced by the teacher in facilitating learning. All the lessons observed were video recorded. Photos to illustrate and demonstrate examples used during lesson presentations were taken after the lesson so as not to disrupt the flow of the lesson.

Teacher 1 is a male teacher teaching Grades 10–12 mathematics. He has a Bachelor of Science degree in mathematics and a post-graduate certificate in education. The teacher is the head of the mathematics, science, and technology department in the special school. He has more than 30 years' experience in teaching mathematics to VI

learners. Teacher 1 has received periodic in-service formal training by the district department of education.

Teacher 2 is a female teacher who has been in a special needs school for three years, teaching Grade 9 mathematics. She holds a post-graduate certificate in education and has received no formal training in working with VI learners. However, her proficiency in the use of information technology has enabled her to learn the skill of translating text to Braille as well as drawing and embossing diagrams with ease.

Data was collected via semi-structured interviews and lesson observations. Six lessons per teacher were observed and videoed. A checklist was used to record the didactical approaches and assistive devices the teachers used, as well as the challenges they experienced. After all the observations were completed, in order to allow the teachers to prepare their responses beforehand, each participant was given a copy of the structured questions before the interviews commenced. The questions focused on teaching approaches, the use of technology to teach VI learners, and the challenges experienced in teaching mathematics in this context. Ethics approval was granted by the University of Pretoria for the study to be conducted and the teachers as well as the learners and their parents/guardians, provided written agreement to engage in the study.

Data analysis was within an interpretivist paradigm with the view that reality is constructed from people's subjective experiences of the external world (Levers, 2013). The data gathered from the observations and interviews were transcribed and analysed inductively to allow categories to emerge (McMillan and Schumacher, 2010).

Findings

The findings of the study are organised according to the three themes: the instructional approaches used to help the VI learners construct mathematics knowledge; the technologies used to enhance teaching, and the challenges experienced by the mathematics teachers in teaching mathematics to VI learners.

Instructional Approaches

The study revealed that scaffolding, contextual linking, direct instruction, problem-solving, and peer tutoring were the approaches most often used by these teachers to teach the VI learners. These specific approaches are also generally to be found in the mathematics classroom of sighted learners, and therefore one may well think that teaching sighted learners is not fundamentally different from teaching VI learners. However, in this study for which the research was conducted in a developing economy, it was found that the way in which these approaches were used by teachers who were not specifically trained to teach VI learners was not always effective.

Scaffolding

Teacher 1 scaffolded learning through simple to complex tasks and handed over the responsibility to learners to practice their skills, but he remained attentive to the concept development of the learners. He guided the learners to understand the concepts of simple interest through a series of questions that gradually increased in the level of difficulty. For example,

Teacher 1: If your principal amount is R100, what do I mean by the principal amount?

Learners: The money that is deposited in the bank account.

The teacher wanted learners to give precise answers in mathematical language, saying, *'that is the initial amount'*. He proceeded to draw more responses from the learners using another example, *for instance, if you deposit R100 into banking account after a year, what will happen to the R100?'* One learner responded, *'It will increase'*. Teacher 1 continued to probe for answers by asking more questions:

Teacher 1: Can you tell me by how much?

Teacher 1: Why is it R10?

Learner: Is 10% of the principal amount. The 10% signifies the interest rate changed on the loan.

Teacher 1 built on the learners' prior understanding of the meanings of interest rates and initial amount or principal amount, to introduce the method of calculating the amount (future value of the principal (A), given principal amount (P), interest rates (i), and the period for which the money was invested (n): $A = P(1+i)^n$).

In another lesson, Teacher 1 explained to VI learners how to calculate the interest rate, as in the following illustration:

$$52000 = 20000(1+i)^8$$

$$20000(1+i)^8 = 52000$$

$$(1+i)^8 = 2.6$$

He then found that the learners had forgotten how to solve the exponential expression by finding the 8th root. He paused to explain, *'to remove the 8, you are going to get the 8th root'*. Teacher 1 spent time helping the blind learners to understand how to get the 8th root using their scientific calculators. After helping the blind learners, he turned to focus on the partially sighted learners. Teacher 1 used an example: *'For instance, if you have $x^3 = 27$ what do we normally do to get the value of x?'* One learner answered, *'Something, times something, times something equals 27, which is three'*. Teacher 1 then asked another follow-up question, *'What did you do to get three?'* The second learner responded, *'We get the cube root of 27'*. Teacher 1 then clarified for them, *'Now, in this case, we do not use a cube root for some reasons it is 8th root . . . in this case, we do not use a cube root for some reasons, it is 8th root . . . Even though it sounds weird, you do get something like 8th root'*. An example of the exercise is provided in the photo (Figure 1). At this point, the learners were able to solve what initially seemed difficult on their own.

Teacher 2 guided the learners on how to simplify a trinomial that starts with a coefficient. She explained, If you have $2x^2 - 4x + 2$, so before you can see your trinomial to factorise, you need to take out the 2 from the $2x^2 - 4x + 2$. What is left is $x^2 - 2x + 1$. Therefore, you have 2 outside the brackets. Teacher 2 then asked a learner to follow the example in solving a similar equation: $3x^2 + 24x + 48$. In another lesson, she moved around helping the learners, showing how to calculate the value of $\frac{x^2-9}{6x-18}$ by asking: *'What can you see on top?'* The learners were supposed to factorise the numerator using

$$\begin{aligned}
 A &= P(1+i)^N \\
 52000 &= 20000(1+i)^N \\
 \therefore (1+i)^N &= \frac{52000}{20000} = 2.6 \\
 (1+i)^2 &= 2.6 \\
 1+i &= \sqrt{2.6} \\
 1+i &= 1.1269 \\
 i &= 0.1269 \\
 i &= 12.69\% \text{ p.a.} \\
 &\text{compounded annually}
 \end{aligned}$$

Figure 1. A teacher’s explanation of the process of calculating the interest rate.

the difference between two squares and to factorise the denominator by putting the highest common factor outside the brackets. Then, in the end, they were to divide the fraction as follows: $\frac{(x+3)(x-3)}{6(x-3)} = \frac{x+3}{6}$

Contextual Approach

Teacher 1 contextualised learning by sketching a scenario of an increase in the price of a loaf of bread from a local supermarket at a specific time. Teacher 1 explained, ‘*Inflation is for instance if you have the price of bread and you must work out what it should be over some time and what it used to be at a specific period.*’ To instil the concept, he guided the VI learners to find how much they would pay for a loaf of bread at a local supermarket in 25 years at an inflation rate of 7% per annum if currently the bread costs R9.40.

So, say a loaf of bread at a local supermarket costs R9.40 and this is now at the end of 2010. How much will you be paying for a loaf of bread in 25 years? Who can help?

Learner: The bread was R9.40, so Principle = R9.40. Then we use $A=P(1+i)^n$

Teacher: What is the inflation rate?

Learner: It’s 0.07

Teacher: That’s correct, and you put to the power of 25. If you look in the brackets what do you do now?

Learner: You first add the 1 with 0.07, because the bracket tells us we do first what is inside the bracket.

In this example, the VI learners connected their new knowledge of inflation to the familiar situation of buying bread in a local supermarket. As Wadlington and Wadlington (2008) argued, learners should not be made to see mathematics content as disjointed units but rather connected and relevant to real-life situations

Direct Teaching Approach

Teacher 1 used direct instruction as he explained the step-by-step procedure of solving a problem while the learners paid attention. He said,

When you deposit money into an account, life sometimes forces you to go and withdraw some of the money from that account because you need it for something. Sometimes you are

lucky and win the lotto, and you want to add more money into your account. That is what happens. In other words, if you deposit money into the account over a period, sometimes you will subtract money from that account and sometimes add money into that account depending on circumstances. This is where timelines come in; what happens is - initially you deposit an amount into the account, and after a year you are forced to subtract or withdraw R2000 from the account. The amount you will have left in the account is less than the amount which was initially in the account.

After a detailed explanation, he used an example in the book to explain how to calculate the remaining balance in the bank after several transactions have taken place.

It was found from the lesson observations that the teachers used direct instruction to introduce new concepts. In one of the lessons, Teacher 1 explained the step-by-step procedure of solving a problem while the learners paid attention. He said,

When you deposit money into an account, life sometimes forces you to go and withdraw some of the money from that account because you need it for something. Sometimes you are lucky and win lotto, and you want to add more money into your account. That is what happens. In other words, if you deposit money into the account over a period, sometimes you will subtract money from that account and sometimes may add money into that account depending on circumstances. This is where timelines come in; what happens is - initially you deposit an amount into the account, and after a year you are forced to subtract or withdraw R2000 from the account. The amount you will have left in the account is less than the amount which was in the account.

He then used an example in the book to explain how to calculate the remaining balance in the bank after several transactions have taken place.

Similarly, Teacher 2 used direct instruction to illustrate how to find the output when the input is given. Afterwards, she provided an opportunity for the learners to practice calculating the value of the output given the formula $y = \frac{1}{2}x - 1$ using input values; -3, -2, -1, 0, 1, 2, 3. She displayed the answers to the question on the closed circuit television (CCTV) screen and read the outcome loudly. She explained how the x (the input values) were used to get the values of y (the output) (See Figure 2).

Problem-Solving Approach

It was also found that both teachers sometimes used a problem-solving strategy in teaching the learners. For example, in one of the observed lessons, Teacher 1 read an example aloud from the learners' textbook and summarised the context of the question. He then drew a timeline sketch and sub-divided it according to the transaction that was carried out on the account. He asked learners to choose the correct approach to solve the problem. Finally, he gave the learners an exercise to do and went around evaluating their answers. This example

$y = \frac{1}{2}x - 1$							
x	-3	-2	-1	0	1	2	3
y	$-2\frac{1}{2}$	-2	$-1\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$\frac{1}{2}$

Figure 2. Example of a teacher' use of direct teaching approach.

generally followed Polya's problem-solving strategy: 'Read the problem; highlight the key-words; solve the problems and check your work' (Jayanthi et al., 2008, p.1210). Teacher 2 used the basic concepts of problem-solving when teaching factorisation of trinomials. In one of her lessons, learners were to identify two factors whose product was equal to the constant, and the sum was equal to the coefficient of the middle variable.

Both teachers made use of peer tutoring because they found that the blind learners took considerably longer than their partially sighted classmates to master graphs and geometric sketches. However, when partially sighted learners were paired with blind learners, they could help the blind learners to construct meanings of illustrations, resulting in accelerated progress for the blind learners. In Lesson 3, Teacher 1 read a question on inflation as follows,

The average rate of inflation over the last ten years was 6.5%. The current price of a packet of 2.5 kg white sugar is R21.50. Calculate the expected price of sugar in 10 years if the rate of inflation continued at the same level.

He grouped the learners in twos. Every blind learner was paired with a partially sighted learner and encouraged to discuss the problem. Teacher 1 warned the learners not to talk about anything else but the work. He then moved around, observing the learners as they discussed and worked through the problem. The group that completed their work first was asked to share with the class their method of calculation and the answer. According to Rule et al. (2011) and Stone et al. (2019), VI learners gain substantially in learning when they are paired to work collaboratively with a sighted peer, discussing and exchanging tutee and tutor positions. Explaining a concept to another person helps build confidence and increases knowledge construction (Steedly et al., 2008)

Assistive Devices

The use of assistive devices in teaching mathematics to VI learners acts as a compensatory mechanism for the loss or inadequate sight (Buhagiar & Tanti, 2011; Smith et al., 2019). In this study, devices used in the school were categorised as follows: devices used to enlarge text, devices used to convert text to Braille, devices used to emboss diagrams, and devices used by the learners to Braille and calculate.

Devices Used to Enlarge Text

It emerged from the study that a Transformer HD, CCTV, Max's mouse and Ruby were used to enlarge mathematics text. A transformer HD is a high-performance electronic magnifier, which was used by the teachers to magnify and project magnified text and diagrams onto the CCTV screen connected to it. The CCTV was a mounted screen in front of every seat where the partially sighted learners could see the teacher's enlarged illustrations and examples in a font comfortable for their sight.

Another device used to enlarge text was a Max Mouse. The Max Mouse was used by the partially sighted learners to zoom in on mathematics text by sliding the mouse over the text and reading the enlarged text on the CCTV screen.

A Ruby is a hand-held device used to enlarge text. The Ruby was used by the partially sighted learners to enlarge a normal text to the correct font for their sight (See [Figure 3](#)).



Figure 3. A VI learner reading with a ruby magnifier.

Devices to Convert Text to Braille

During the observations, it was found that the Scientific Notebook, Math Type and Duxbury (DBT) computer program helped the teachers convert mathematics text to Braille. During the interview, Teacher 1 demonstrated how to convert print text to Braille. Teacher 1 opened a document that he had already set up for a Grade 10 assignment regarding loan repayments in financial mathematics. He explained while scrolling down the document:

If you look further down in the text, you can see that we make use of the normal formulae, like the compound interest formula: $A = P(1 + i)^n$ simple interest formula $A = P(1 + in)$ and the conversion of the different interest rates, from nominal to effective $1 + i = \left(1 + \frac{i^m}{m}\right)^n$

He saved the document on the desktop and opened a program named DBT. He then explained, 'Duxbury is a computer program that helps us to translate any Word program into Braille'. He opened the saved file using the Duxbury program and another panel popped up from which he chose UEB (Unified English Braille). UEB is a type of Braille code that was adopted in South Africa in 2004 (Cryer et al., 2013). He then clicked on the word translation code and explained, 'I am going to choose Grade 2 Braille, which is contracted Braille that has appropriate Braille code used for blind learners in high school'.

Teacher 1 translated the whole assignment into Braille by pressing the button marked translate. The assignment was then printed using a Braille printer and issued to the learners See Figure 4.

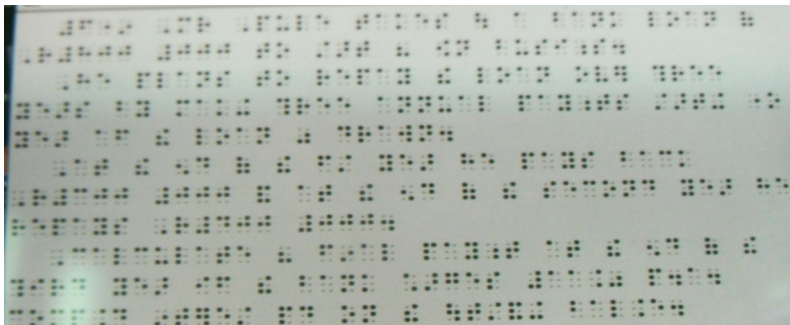


Figure 4. A translated braille texts.

Devices Used to Emboss Diagrams

The teachers in this study used Tactile View and View Plus computer program together with the tiger printer to produce embossed sketches, tables, and graphs. During an interview, Teacher 1 indicated that he uses the View Plus computer program to make sketches, graphs, tables and other diagrams to be embossed. He demonstrated by opening a sketch in Word: *The parabola graph is already sketched in a Word program. I have put on the subtitles already. I now need to translate everything on the sketch*. He clicked on the program, and a list of icons popped up. He then clicked on View Plus for translation. The sketch and all subtitles were translated. The translated sketch was then printed in the tiger printer (a 3-D printer) as shown in Figure 5.

Devices Used by VI Learners to Braille and Calculate

There were two types of Perkins Brailers in the observed classes, a standard Perkins Braille, which is generally heavy and noisy while in use, and a next-generation Braille, which is light, with less noise, and creates high-quality Braille. Additionally, the blind learners used a scientific talking calculator for computation. Teacher 1 said, *Braille talking calculators in the school accommodates all the different calculations that are in the syllabus from Grades 10–12. In other words, you get all these trigonometrical calculations on the calculator.*

Teacher 1 gave an example of how the calculator is used in calculating compound interest. He calculated the interest rate $(1 + i)^8 = 2.6$. He explained that *Scientific talking calculators don't have the function to handle this 8th root of 2,6 because we need to get the 8th root of 2.6. What I normally teach them is to raise $2.6^{\frac{1}{8}}$. According to the exponential law that says the 8th root should be equal to the power of $\frac{1}{8}$* . He said at this point, blind learners first solved for the value of $\frac{1}{8}$ using the calculator, which equals 0.125. Teacher 1 would then write $1 + i = 2.6^{0.125}$. And then, using the calculator, he calculated 2.6 to the power of 0.125 = 1.126864425 ... Then $1 + i = 1.1269$. Then subtracting 1 from both sides, this resulted in $i = 0.1269$, which is equal to 12.69%

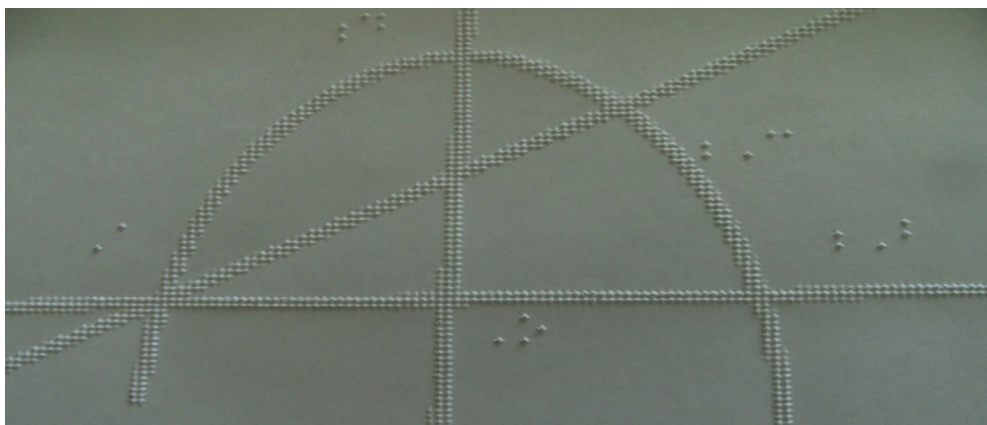


Figure 5. Embossed diagram from a tiger printer.

Challenges Experienced in Teaching Mathematics to VI Learners

Lack of Skills and Knowledge in Teaching VI Learners

Many scholars such as Bayram (2014); Fraser and Maguvhe (2008); Sahin and Yorek (2009), argue that unskilled and inexperienced teachers find teaching mathematics to VI learners very challenging. Teacher 2 had not received formal training to teach the VI learners. During the interview, Teacher 2 expressed her discomfort in teaching some of the measurement topics, stating, *'I find it difficult to teach topics on measurement, and it is quite challenging'*.

Time Constraints

The response from the teachers revealed that they are constrained by time to cover the prescribed syllabus without extra teaching after normal school hours. During the interview, Teacher 1 said.

The pace at which you teach the blind learners is slower, and it becomes a battle to cover the syllabus on time. Sometimes you are forced by circumstances to be very crafty when it comes to your lesson preparation and presenting within time constraints.

Teacher 2 explained, *'Teaching mathematics to VI learners requires extended time above normal school hours'*. She indicated that the VI learners were very slow in working through activities. Concepts had to be explained two or three times, which takes time. She also said, *'I have an extra class to help them with basic concepts and contents covered earlier in the year to enable them to practice and memories'*. Other studies have revealed that the writing and reading of Braille material takes longer than the writing and reading of the standard text (Bitter, 2013). This is because Braille readers can only read the character under their fingers one at a time (Sedaghatjou, 2018). Negash (2017) also argues that providing individualised teaching is time-consuming and may lead to the set syllabus not being completed timeously.

Lack of Home Support for the Learners

Many parents of these VI learners were not actively involved in the schools' activities despite being informed of the benefit in their involvement. For instance, many parents did not attend school meetings or participate in their children's education. Teacher 1 stated that *'Most VI learners lack home support structures, which have a great impact on their learning'*. This means they are not assisted with homework or assignments given by their teachers. Teacher 2 claimed, *'I give extra work every week for them to submit a week later. The papers come back empty, half-done, or with no calculations at all'*. According to Hirano and Rowe (2015), when families support their children through involvement with their homework, they influence student's motivation for completing homework.

Bulky Braille Books and Missing Information

Many volumes of Braille books equate to one sighted learner's textbook. For example, the Grade 9 Platinum Mathematics sighted book is equivalent to 18 bulky Braille books, 8 activity books, and 10 diagram books. It is difficult for learners to carry bulky books beyond the classroom. In the interview, Teacher 1 said that she sometimes found it

difficult to assist blind learners with the correct volume that correlated with the sighted learners' book, and even more difficult to locate a specific page for the activity. Occasionally the teachers come across missing information in the braille books or incorrect information. This forces the teacher to provide the missing text in Braille and correct the errors in the given text, all of which demands additional time.

Technology Failure

Teacher 1 had to resort to oral teaching without displaying illustrations on the CCTV screens when these failed to work during the lesson. In the interview, he said, *'Sometimes we experience a challenge when the computers and the printers are faulty'*. This meant that blind learners had nothing to read. Assistive devices are important in the learning of mathematics by VI learners as they help minimise their barriers to learning (Daroni et al., 2018). Therefore, their availability improves the quality of teaching, and their unavailability causes a challenge for the teacher.

Conclusion

This case study explored mathematics teacher's instructional approaches, assistive devices, and challenges in teaching VI learners in high school. The approaches used in teaching mathematics in mainstream schools were generally the same as those adapted to teach VI learners, but adaptation for the VI learners depended on the experience and skills of that teacher. To succeed in teaching mathematics to VI learners, the incorporation of assistive devices is not only vital but unavoidable. These most essential devices were those used to enlarge the mathematics text to the correct font, convert the text to Braille format, and to emboss diagrams. The sampled teachers did not experience overcoming individual differences between the partially sighted and profoundly blind learners in their class as particularly challenging. In fact, they found it useful to group partially sighted learners with profoundly blind learners when it came to putting into practice what had been taught in a particular lesson. The greatest challenge experienced by these teachers was their lack of skills and knowledge in this very specialised teaching context, inadequate knowledge of the mathematics Braille code, time constraints, lack of learners' home structure support, bulky Braille books, and missing information in the books, as well technology or even power failures. Teaching and learning in the VI context can at best be described as complex and worthy of state intervention.

Recommendation

The South African government's obligation, as found in White Paper 6 special education needs, stresses the need for equipping special needs schools with resources and professional skills to cater to the needs of the learners despite their disability. The authors of the article recommend more government support to teachers teaching mathematics to VI learners in public special schools through organised workshops and in-service training. These teachers will then develop knowledge and skills in teaching mathematics to VI learners and be motivated to offer the subject at secondary school level.

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