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Analysing the physics learning environment of visually impaired students in high schools

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Abstract

Although visually impaired students attend regular high school, their enrolment in advanced science classes is dramatically low. In our research we evaluated the physics learning environment of a blind high school student in a regular Dutch high school. For visually impaired students to grasp physics concepts, time and additional materials to support the learning process seem key. Time for teachers to develop teaching methods for such students is scarce. Suggestions for changes to the learning environment and of materials used are given.

Introduction

In engineering, science, technology, and mathematics, information is often expressed in graphical representations (Zebehazy & Wilton, 2014), graphs and pictures. For visually impaired high school students this manner of receiving information is a challenge, since they both experience the world differently than people with full vision, as well as being unable to receive printed information. In Western cultures, 75% of visually impaired children follow regular education in primary or secondary school (American Foundation for the Blind, 2017). The remaining visually impaired children are in special education. Laws on inclusive education oblige schools to admit children with special needs into their regular educational programs, and to supply the extra support needed to ensure their success (Ministry for Education, Culture and Science, 2016, e.g.). Most visually impaired children have learned to read braille (Boswinkel et al., 2012).

It is known that visually impaired students often struggle in getting an education, especially in the sciences (Boswinkel et al., 2012; Dunkerton, 1997). Research on teaching sciences to the visually impaired is scarce (Erwin, Perkins, Ayala, Fine, & Rubin, 2001; Azevedo & Santos, 2014) and is limited to studying individual possible additions to classroom materials (use of relief drawing boards, tangible graphs) that teachers themselves need to design and create.

The research presented here is part of a larger project that focusses on the design and evaluation of an approach to teach a complete physics subject to visually impaired students, involving student, teacher, and publisher of educational materials. In this article we will describe the physics learning environment of a visually impaired student and present

design criteria for teaching materials to facilitate teaching the physics of sound to a visually impaired student.

How visually impaired students learn

A human being can see multiple objects at the same time, but can only explore one object at a time through touch or hearing. In learning, an estimated 80% takes place through sight (Hill & Blasch, 1980). Therefore, visually impaired students need more time to process information than regular students (Van Leendert, 2008). Visually impaired students benefit from education that has a strong emphasis on language (Millar, 1997). Although visually impaired students in general have the same learning abilities and curiosity as their sighted peers, they are often enrolled in a lower level of education than peers with similar capabilities (Boswinkel & Van Leeuwen, 2008; Azevedo & Santos, 2014).

Visually impaired students often need intensive help from a teacher or a sighted fellow student (Adam & De Groot, 2006). Teachers in regular high schools often do not have the time to provide the visually impaired student with the necessary assistance (Van Leendert, 2008). In science teacher education no specific attention seems to be placed on the learning of visually impaired students (De Putter - Smits & Van Driel, 2016), rendering even an experienced teacher into a novice. In addition, the visually impaired student can become a very passive learner when the teacher or the fellow student are too quick to divulge the information that needs to be acquired (Adam & De Groot, 2006).

The cooperation between a visually impaired student and a regular student is valuable from a social constructivist point of view. The way both students learn tends to be different, providing a learning opportunity for both (Van Leendert, 2009). Active involvement, interaction and discussion are essential when learning scientific concepts (Erwin et al., 2001). Since one of the students has no disability, the practical assignments do not require as many changes as when a visually impaired student would attempt them alone (Dion, Hoffmann, & Matter, 2000). The active involvement of the visually impaired student in a practical assignment will unfortunately then be limited.

Learning STEM subjects can be a challenge for visually impaired students, for instance, it is difficult for them to estimate distances, surfaces, and volumes, as well as interpreting graphs (Rule, Stefanich, Boody, & Peiffer, 2011). Another issue are the mathematical notations that were never included in braille script (Boswinkel et al., 2012). The development of mathematical skills in visually impaired students depends on the natural ability, the remaining vision, the age at which the student became blind, and the environment the student grew up in (Boswinkel et al., 2012). The learning environment the student experiences is one of the few factors that can be influenced and optimised, and therefore is the most important factor in developing mathematical skills. Research has shown that tactile materials and audible graphs could be used to aid the teaching of mathematics and physics to visually impaired students (Supalo, Humphrey, Mallouk, David Wohlers, & Carlsen, 2016; Zebehazy & Wilton, 2014).

For visually impaired students of physics there are two kinds of limitations. The first one is that they perceive the world with different emphasis (touch rather than sight) than regular students (Hill & Blasch, 1980). Second, the subject as it is taught uses pictures, diagrams, schematics and tables that are inaccessible to them (Azevedo & Santos, 2014). Visually impaired students often miss out on certain information, or they need to acquire the

information differently than their full-sighted peers (Boswinkel et al., 2012). The image of a scientific concept formed in the learner's mind depends on the metaphors and analogies the student is already familiar with (Gilbert, 2010). Visually impaired students are more likely to develop misconceptions through the information received. For instance the definition of light as *electromagnetic radiation visible to the human eye, represented as light rays*, makes no sense to a blind person (Azevedo & Santos, 2014).

Summarizing, visually impaired students need more time to process the information given, they are more dependent on others to explain concepts, and they are generally less active in practical assignments, which in many cases leads to under-performance. Studies into how visually impaired students experience physics education are not available. Therefore, the present study will focus on the analysis of the physics learning environment for a visually impaired student in a regular high school. The research questions in this study are:

1. How can a physics learning environment for visually impaired students be described
2. What limitations are there for physics teachers when teaching physics to these students?

Method

Participants

This research is qualitative in nature. It was conducted in a Dutch high school that accommodated a year 10 visually impaired student in a regular physics class of 28 for the first time in the school's history. The school is situated in the middle of the Netherlands and is attended by approximately 1100 (regular) students. The teacher, the mentor, and the visually impaired student all voluntarily agreed to participate in this research. The parents gave their consent for the student to participate in the research project.

Visually impaired student. She is 14 years old and has a remaining vision of 0.5%. She can determine the difference between day and night but in practice her vision is negligible. The student has accepted that she is blind and does not mind talking about it.

Physics teacher. He (36) had been a physics teacher for 11 years and had no previous experience with teaching visually impaired students.

Mentor. He (34) had been teaching geography for four years. Besides the student's mentor, he was also her geography teacher. He had no previous experience teaching visually impaired students.

To answer our research question, four lessons were observed: two on optics and two on electricity. From these observations more in-depth questions on teaching visually impaired students were identified. These questions were used in semi-structured interviews with the teacher, student, and mentor. The findings from these interviews were subsequently discussed with the participants for confirmation.

Instruments and analysis

All lessons observed were recorded using two video recorders: one pointing at the electronic board (Smartboard) and one at the visually impaired student. The recordings were combined into split screen recordings. During the observations notes were taken on the problems occurring per learning activity, such as struggles with electronic diagrams, descriptive text on light rays, and the use of graphs. From these observations more in-depth questions on teaching visually impaired students were identified, which were then used in a semi-structured interview with the three participants. Topics in these interviews were:

- Subject specific questions: were the teaching goals achieved?
- Progress: what is the teacher's, visually impaired student's, and mentor's opinion on student progress?
- Other: questions not pertaining to physics but to learning in the social setting (school, peers, acceptance from others).

The semi-structured interviews were recorded. A minute to minute transcript was made from these recordings. The transcripts were then analyzed and coded using a grounded theory approach. The categories found were: general learning environment and limitations in time, materials, assessments, and communication.

To check reliability of the coding process, raw data and codes were given to a second researcher (last author) to check for accurateness, completeness and to verify overall conclusions drawn. Based on a discussion of the findings, both researchers come to overall consensus of the codes and conclusions.

The time the teacher spends specifically on the visually impaired student has been marked down from the split screen recording of the lessons. A percentage of the total lesson time spent on this student was calculated.

The physics learning environment and its limitations

General background

From the interview with the teacher it became apparent that he heard he would teach a visually impaired student a few days before the start of the school year. This left him very little time to prepare for such a student. He felt thrown in at the deep end.

Teacher: When you teach a visually impaired student you miss particular knowledge. A manual would be useful, but what would you put in ...?"

A fellow physics teacher refused to teach the visually impaired student. The colleague, that was a few years from retiring, could not see how he could adapt his teaching. The mentor agreed that there were quite a number of teachers that were reluctant to teach a visually impaired student. The main reason for opposing was the lack of preparation time. The reluctance subsided during the school year. The visually impaired student appeared to be more intelligent and self-reliant than was assumed, requiring less help than expected.

The visually impaired student is dependent on a fellow student and or the teacher for help. This dependance is experienced by the visually impaired student as annoying, for instance during a practical activity. The visually impaired student is necessarily passive in doing an experiment. The fellow student talks the visually impaired student through what is being done, leaving the visually impaired student to try and understand what is going on. In a word document the visually impaired student can then report what, in her opinion, was done in the experiment.

The teacher viewed teaching the visually impaired student as a challenge, but most of all as a good learning experience. During the school year, the teacher found a balance between the one-on-one time the visually impaired student needed and the time he spent on the other students. He considered it a waste that all the knowledge he now has on teaching a visually impaired student will be lost in the following school year, since another teacher will be teaching physics in year 11. According to him, a visually impaired student should have the same teachers and mentor during her entire school career. The mentor added to this that regular high schools that accept visually impaired students all reinvent the wheel, every year.

Time

From the interview with the physics teacher it became apparent that the teacher is not provided with extra time by the school management when the school accepts a visually impaired student in regular classes. The teacher indicated that he wanted and needed to spend extra time, which he did: his own private time. Ethically, for him the question arises: how much time should I spend on this one student and how much time do I want to spend extra on this student?

The teacher prepares each lesson with the perspective that the content should be explicable to both the visually impaired student and the regular students. The teacher indicated that for this class he spent ten to twenty minutes extra per lesson in lesson preparation time.

The observations of the lessons revealed that the central explanation offered to the class is not sufficient for the visually impaired student to grasp the concept at hand. The student requires one-on-one time with the teacher to clarify the concept. It was observed that the visually impaired student on average asks 10 questions during this one-on-one conversation. Of the total lesson time, the teacher spent on average of 20% solely on the visually impaired student. Her 27 classmates did not receive any of the teacher's attention during this time.

Materials

The regular physics textbook was converted to braille prior to the school year. The braille physics book for year 10 consists of 21 ring binders. Interviewing the publisher, it became apparent that the physics textbook was literally translated into braille. For primary school materials there is a standard adaptation procedure when converting to braille: the materials are read (in braille) to ensure the meaning is still clear and the assignments doable. Minor adaptations to support the visually impaired student are then made where necessary. The publisher indicated that they have no means and knowledge

to do the same for textbooks in secondary education. The strategy is to enhance the self-efficacy of the visually impaired students when they get older, so that they learn to help themselves by asking questions or finding their own solutions to problems they encounter because of their condition.

Observations show that the textbook contained assignments that do not match the visually impaired student's perception of the world. In assignment 45: *In figure 67 you find a photograph of lightning hitting the Eiffel tower. Lightning strikes a high building easier than the earth's surface. Why is electricity better conducted through the Eiffel tower than through air?*" (page 79 - braille textbook).

Visually impaired student: *"I can't do that, because I cannot use this figure."*

Classmate: *"You don't need the figure at all."*

Teacher: *"Yes you do.... if you do not know what the Eiffel tower is."*

Classmate: *"You don't know what the Eiffel tower is?"*

Visually impaired student: *"I know what it is, but not what it looks like."*

Teacher: *"Do you know what the Eiffel tower is made of?"*

Visually impaired student: *"Wood I think..."*

This dialogue demonstrates how differently the visually impaired student interprets the question.

Out of 13 assignments on mirror images in a chapter on light, only three were doable for the visually impaired student, since they rely on figures. This was visibly confronting to the visually impaired student.

From classroom observation it became apparent that blackboard animations, as a way to construct a phenomenon, are too complicated for the visually impaired student to follow. The visually impaired student has to rely on the oral description of what is being done on the board to recreate the phenomenon. The teacher indicated in the interview that it is difficult for him to constantly remember to exactly describe what he is drawing, whilst he is drawing.

The visually impaired student types answers to assignments in a Word document, using a laptop with braille keyboard. She checks her answer using a digital (speaking) answer book, meant for the teacher. From the student interview it became clear that this answer book is flawed in physics content and partly inaccessible due to the use of tables. Limitations of the braille book, other than the large number of braille ring binders necessary for one year of learning physics are:

- Sometimes one paragraph was split up in two separate ring binders.
- The textbook refers to sections that are not in the same binder the visually impaired student is currently working from, and is thus inaccessible in class.

- In the textbook, important concepts are italicised, an option not available in braille.
- Classmates and teacher are unable to read braille, and are thus unable to interfere in the use of the textbook

Although the latter could be solved by using an online version of the textbook, the student feels uncomfortable using a laptop for long periods of time. She prefers written braille books.

Assessment

From the teacher interview, limitations in assessment included the lack of braille assessment options, the avoidance of figures, tables, graphs, and drawings in a test. For a subject such as light, where many drawings and figures are used, this resulted in the teacher asking the visually impaired student to report in a Word document what she had learned from this chapter. She scored a 6.5 out of a possible ten points.

Teacher: "As a teacher I grade the test based on what the visually impaired student could have grasped. Physics is based on observations, logical reasoning, and then building on to this. For visually impaired students this is difficult."

The teacher also indicated a struggle with providing extra assignments; he does not have more to offer than the assignments in the braille textbook. The number of assignments the visually impaired student can use to prepare for a test is thus limited.

The teacher mentioned that the visually impaired student also takes advantage of her disability. Confirmed by the observation, the visually impaired student is sometimes quick to skip an exercise or to ask the answer from the teacher or a fellow student. During the interviews it appeared that a test made by the visually impaired student on her laptop had gone missing once. Both teacher and student felt they were not responsible for this loss. The visually impaired student did not consider it a great loss, since she felt she did not do well in the test.

Communication

The teacher and mentor were unaware of additional teaching materials available in the school, such as a relief drawing board, where line drawings become tangible (they swell up). Also relief drawings and assessments (to be converted into braille) could be specially ordered from the publisher of the braille textbook. This would have allowed inclusion of the visually impaired student in regular test environments. Since none of the teaching staff were aware of this possibility, these materials were not available.

Conclusions and discussion

This research has provided some pitfalls when it comes to teaching physics to the visually impaired. Issues in the physics learning environment are the time needed to prepare and teach a class with a visually impaired student, the teaching materials used, assessments, and communication.

From the interview with the physics teacher it became apparent that the teacher is not provided with extra time by the school management when the school accepts a visually impaired student in regular classes. Teaching a visually impaired student however, requires adapting materials, specifically for the student and the subject at hand. Also during class, a substantial amount of time is needed one-on-one to ensure the visually impaired student grasps the concepts correctly. For the school management it seems key to inform teachers of all the possibilities surrounding the learning process of a visually impaired student. Supplying teachers with time to develop and order the appropriate materials should improve the learning of physics.

The converted textbook contained a lot of content that was irrelevant for the visually impaired student, including descriptions and referrals to inaccessible figures, formulas and tables, and unworkable assignments and experiments. A redesign of the book and the assignments by a braille reading physics teacher is necessary to reduce the content and render it fit to teach visually impaired students, especially in situations where the book is supposed to be self-explanatory.

Pictures and graphs can be made accessible by converting them to relief drawings or designing 3D models that aid the concept conveyed in the original. If the additional materials are expected to be self-explanatory, an experienced physics teacher will need to aid in the design to convey the concept correctly.

A relief drawing board can be useful when teaching, as the teacher in our study discovered nearly after the fact.

All the previous factors combined would lead to a complete redesign for a physics learning environment fit to teach a visually impaired student. Since, in this school studied here at least, not many visually impaired students attend physics the cost of such a design would not outweigh the benefits, to most school management. If more visually impaired students would want to study physics however, an adapted learning environment seems a good place to start. The attitude towards physics (and mathematics) of the visually impaired student in this research has changed for the worse during the school year. She found the subjects difficult and uninteresting. Compared to other subjects her grades for physics are considerably lower. When discussing this research on the *Blind Science Conference* a physics teacher who was teaching a gifted visually impaired student in a regular high school disclosed he encountered challenges on a different level to the one we encountered in this research. This indicates that motivation and ability to learn are important factors in this kind of research, and thus should be taken into consideration in future research.

Although adapting the study materials might well lead to a better understanding of physics, however, as (Millar, 1997) and (Van Leendert, 2008) state, visually impaired students still need more time to process new information, since touch and sound are successive processes in the human brain (as opposed to sight and sound). Another factor that strongly influences the learning of physics is the age at which the student has become visually impaired and the extent to which the vision is impaired.

The research was focussed on electricity and optics, but the physics curriculum is extensive, leaving room for research in how to teach all the areas of physics to visually impaired students. Since the group of visually impaired students that attend physics in regular high school education world wide is small there is not much interest in generating materials for learning physics to those using braille, let alone researching the learning outcomes. This is unfortunate, since with the modern means to produce both braille books and 3D models and graphs this group could be helped forward in learning physics.

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