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Practical work in science with visually impaired students

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The mission of science education, in terms of school establishments, is to prepare individuals who would develop a certain level of scientific understanding and basic scientific process skills. Developing basic scientific process skills requires practice in and out of school. Therefore, practical work is seen as a prominent feature of school science teaching in many countries, and it is acknowledged that good quality of practical work promotes the engagement and interest and curiosity of students as well as developing a range of skills, science knowledge, and conceptual understanding. Learning science requires intensive use of the senses, particularly the eyes in order to be a good observer. However, some of the individuals, have difficulty in using their eyes due to visual impairments. In this chapter, visually impaired students' needs in carrying out practical works and learning science are discussed. In addition, sample learning materials which were developed to meet those students' needs are presented. Recommendations are made how to adapt the science curriculum to visually impaired students.

Introduction

Why do we teach science? This is one of the central question that we ask for ourselves as science educators. Although there is a vast amount of literature discussing this question in science education (e.g., National Research Council, 2007), it is still an ongoing discussion. There is no simple answer. Reasons for science education can be brought under two broad aims. These are:

- To train the workforce for the future that have knowledge and skills necessary to promote economic, scientific and technological development; and
- To give future generations an understanding of scientific and technological knowledge and life skills to help them to be able to make informed decisions in their life and in society.

These two purposes are indicating the importance of ensuring that future generations have a better education in science so that, as citizens of tomorrow's society, they can engage critically and creatively with opportunities and issues in science.

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The term 'practical work' is defined differently in various places. For instance, Hodson (2005) used the term 'practical work' "*for any classroom, laboratory or field activity that involves the use of scientific apparatus, chemicals, biological specimen or scientific models, either by students or their teachers*" (p. 30). In other places, practical work is considered as "*any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the objects or materials they are studying*" (Millar, 2010, p. 109). In some part of the world, practical work is seen as a natural part of any science teaching, as it is the case for UK (Abrahams & Millar, 2008; Abrahams & Reiss, 2012). The main reason for using practical works in science teaching is based on the argument that it can motivate students towards the study of science, although there is evidence suggesting that whilst it generates short-term engagement, it is relatively ineffective in generating motivation to study science at post compulsory level or provoking long-term personal interest (Abrahams, 2009; Hodson, 2005). More arguments other than 'affective arguments' for the use of practical works in school science teaching, include skills development, conceptual understanding of basic science concepts, development of procedural knowledge for scientific method and nature of science (Millar, 2010, p. 110). However, there are disappointing research results for teachers, teacher educators, and curriculum developers that practical work does not always produce the expected motivation, learning gains, skills and attitudes. From the most optimistic and realistic view it could be argued that "*some teachers use it successfully with some students to achieve some of their goals*" (Hodson, 2005, p. 31). A lengthy discussion on why practical works do not always work and how they can be best implemented can be found elsewhere (Abrahams, 2009; Abrahams & Millar, 2008; Abrahams & Reiss, 2012).

Students with visual impairment are required to complete the same curriculum and examinations as sighted students. However, due to the nature of science and mathematics, the majority of the education resources and instructional methods are based on vision, which is partly or not accessible at all by visually impaired students. There is a need for adaptation in the educational resources and methods for the needs of individuals with visual impairment. Although there are some guidelines (i.e. Dion, Hoffman, & Matter, 2000) how to adapt educational resources to the needs of visually impaired students, there is still a huge gap in how to adapt educational resources and instructional methods to the needs of them as they are a heterogeneous group. Students with visual impairments differ in intellectual ability, development rate, social competence, and other factors. In addition, they differ in terms of their impairments, the extent of their visual acuity, and their ability in using the whatever vision they have too. Even if they have the same identical acuities and fields of vision, this does not mean that they use the vision they have in the same way and capacity. Teachers should understand students' needs, be aware of their own capabilities, knowledge and skills, and also the facilities available in the school. As instruction is generally done in groups, it is also important to understand the nature of visually impaired students as a whole, while teachers need to know all factors that influence each student learning.

As it is the case for all disabilities, it is true for visually impaired students that they have been discouraged from learning science, technology, engineering, and mathematics (STEM), and as a result they are underrepresented in the STEM workforce (Supalo & Bodner, 2012). Visually impaired students are coming to the science and related courses with misconceptions embedded in mind, from either themselves or their teachers, that science is difficult and not accessible for them. Moreover, parents and employers are having doubts as to whether a visually impaired person can manage STEM related careers. In order to overcome this problem, there is a trend in the world that all classrooms have to be barrier-free. With the encouragement and help from the science education research community, it is believed that major barriers will be addressed and students with visual impairment be able to access science classrooms and achieve as same with their sighted peers. A review by Mastropieri and Scruggs (1992) documenting research in science education for all disability groups resulted with 14 reports out of 66 reports being investigated. Taking this figure into account, Sözbilir et al. (2015) suggest the emergence of interest in science education research community is encouraging, although the number of research reports in teaching science to visually impaired students is still quite low compared to the entire science education research literature. Therefore, there is a strong need for research in this area to produce evidence-based practices in large scales. Current literature indicates that the majority of the studies are still at a very beginning stage and they focus on different topics in science such as motion, electricity, development of scientific process skills, and inclusion. On the other hand, although the numbers are not high, studies vary from teaching primary science concepts (i.e. Wild, Hilson, & Hobson, 2013), biology (i.e. Fraser & Maguvhe, 2008), chemistry (i.e. Lewis & Bodner, 2013), physics (i.e. de Azevedo, Vieira, Aguiar, & Santos, 2015). Research on teaching science to visually impaired students in Turkey is limited. Only a few number of studies have been done by a small group of researchers working on teaching and learning science for visually impaired students (Bülbül, 2013; 2014; Karakoç, 2016; Okcu & Sözbilir, 2016).

Science has been considered as one of the major subjects that can be taught to students with disabilities. Potential benefits of science education for students with disabilities are described by Mastropieri and Scruggs (1992) as (i) expanding experiential background for students who have had limited experiences; (ii) covering skills and knowledge important for adult functioning; (iii) using concrete, hands-on learning activities; and (iv) developing, through science activities, problem solving and reasoning skills. Science would be beneficial for students with visual impairments because it may allow them to develop compensatory skills for observing, manipulating, and classifying phenomena and related matters. However, science education typically has received little emphasis in classrooms with visual impairments (Supalo & Bodner, 2012). There might be several different reasons for this figure such as special education teachers may have little training in science, they may have difficulty obtaining relevant materials, or because they may find little time left for science after extensive allocations of time for basic skills instruction (Mastropieri & Scruggs, 1992). Regarding the upper grades, subject teachers such as science teachers although they know the subject may not have any kind of training for teaching visually impaired students, they may not be able to adapt the current curriculum to the needs of those students or may not be able to access to the tactile materials or equipment to produce these materials.

Purpose and research questions

An important issue relevant to the implementation of science education for students with visual impairment is whether the promise of science education for such students has been supported by available research evidence. Questions that arise are: What are the needs of visually impaired students in learning concepts and skills relevant to science? Can students with visual impairment be efficiently taught basic science concepts, critical thinking and scientific process skills? If so, which methods or adaptations of methods and materials have been seen to be the most effective in delivering science education? This study is aimed to provide a broad aspect to these questions on the basis of evidences and experiences gained working with visually impaired students in the last three years of my research group. In particular, answers to the following question will be sought:

- What are the needs of visually impaired students' in carrying out practical works?
- How these needs could be met in designing instructional materials and activities for practical works?

By answering these two basic questions we will be able to differentiate the individual needs of students with visual impairments as they display great variability among them. Practical works are important to gain first hand experiences in teaching science, however it is challenging in terms of adjustments in terms of time frame, adequate facilities and teachers' skills, and classroom management. Therefore, teachers abstain from doing practical work although students are mostly willing to do so. A second important aspect is to understand visually impaired students' needs in learning science concepts. As it is described above, visual impairment may be adventitious or congenital. Congenital blindness cause lack of development of visual memory which inhibits development of basic concepts. Therefore, it is important to consider their needs in designing instructional materials and activities for practical works.

Research design

This study is a part of large scale research project funded by TUBITAK (The Scientific and Technological Research Council of Turkey) under the contract number 114K725. The whole project is designed as a design-based research (DBR). DBR "*blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice*" (Design-Based Research Collective, 2003, p. 5). However, the part of the project which presented in this paper is mostly based on the first stage (analysis) but present some of the data from second (design) and third stages (implementation). At the first stage students with visual impairments needs were investigated related to learning science. This was done by observations made in classrooms during science teaching and interviews carried out with students and their science teachers. Unstructured observations were conducted in classrooms from a special middle school for visually impaired students in Erzurum city centre. The observed classrooms included six visually impaired students at 6th grade, five visually impaired students from grade 8th. Among the students there were both low vision and blind. One of the blind students was congenitally blind while the others were adventitious blind. The sample was showing great variability. Observations were conducted periodically throughout the second semester of the 2014-15 academic year. Data collected included videotape and audiotape records, field notes, and interviews of students and the teacher. Interviews sought students' needs on learning science as well as individual needs and preferences. Science curriculum units were also examined.

All interviews were transcribed verbatim for analysis. All qualitative data were analysed through Nvivo 10. The results regarding the needs of visually impaired students' in carrying out practical works and learning science concepts were described in the findings and guidelines that were developed for instructional and materials design. Sample instructional materials and instructional designs were presented under findings and the outcomes are discussed in the results section.

Findings

The units observed were from grade 6th science course covering the topics of reproduction, growth and development in plants and animals from a life sciences unit; matter and heat from a matter and change unit; and conduction of electricity from a physical phenomenon unit. Although all aspects of teaching and learning activities were observed in the classroom, only the aspect related to practical work and learning science concepts are reported here.

It was observed that the majority of the teaching was based on lecturing, with not much adaptation of materials or instructional setting to the needs of visually impaired students. The main reason for this is the teacher's inexperience in working with visually impaired students. The teacher had more than 10 years of experience in teaching science, while her experience working with visually impaired students was only less than three years. She neither received any kind of training for this particular group of students nor took any kind of professional development support, other than the support received from the special education teachers in the school through informal interactions.

Most of the adaptations or interventions were done by the teacher based on her own experiences. The teacher's experience was limited; her teaching was mainly based on lecturing. From time to time the teacher brought some materials into the classroom or did demonstrations. However, demonstrations were only for low vision students. Therefore, blind students were not able to get any benefit of it. The materials used were designed for sighted students with no braille typing or guidelines. All the guidelines were based on oral explanation. Therefore, classroom observation indicated that students were mostly passive during instruction. It is most likely that due to this reason, during the interviews, students characterized science as 'difficult' and 'inaccessible'. In order to identify the visually impaired students' needs related to science learning data gathered during the interviews and observations were analysed and the major results are described below.

It appeared that among the most important need is the material and the activity which is designed according to the needs of visually impaired students with different visual acuity or tactile materials in the case of blindness. Although there are some materials available in the school, they are designed for sighted people. In order to overcome this difficulty, it was decided that all science teaching has to be based on some kind of practical works with accessible materials. The second stage of the designing of instructional materials were the identification of the students' individual needs. In order to be able to understand how much of the vision can be used by low vision students, functional vision evaluation has been carried out by a group pf experts working at the department of teacher training for visual impaired students in Gazi University, Ankara. This group is also taking part in the project. The functional vision is evaluation based on how students are able to use the vision they have. This is important as every individual is not the same in terms of using the vision. In cases, some individuals with only very low vision are trained themselves to use it, while some of the individuals with even better vision compared to others may not be able to use it functionally. A functional vision evaluation includes the eye condition, focusing objects from different angles, following objects, seeing objects in close distance (seeing 1cm objects in less than 60 cm distance), identification of colours, acuity in contrast, reading, writing, and seeing from a distance (seeing 10x10 object from 1 m distance). Based on the data obtained from the functional vision evaluation, it was decided that enlargements in the texts are needed and the minimum size for the printing documents has to be printed with font size at least 20 and the best font is the Century Gothic. Century Gothic fonts are also found the best fonts for low vision students (Arter, Mason, McCall, McLinden, & Stone, 1999).

The most important need identified is for materials that students can use during and after class time. Teaching based on the instruction is only available in the classroom. As the majority of the students are weak in skills in note taking, they mostly listen the teacher but they forget what they learned soon after the teaching. During the interviews students were complaining about the lack of materials that they can use in and out of classroom. Having written notes are also important for students to carry out any kind of practical work by themselves without relying on teacher. By taking this point into account, all instructional design included handouts to be used either during the classroom or after the classroom for revision purposes. Having revisions notes is important for visually impaired students even if they have some vision and be able to read normal textbooks. Normal textbooks are written for sighted student and they are not always able to read it. Therefore, low vision students have to use technological aids or magnifying equipment. This equipment is either not available or not accessible out of school time. Therefore, students have to use a hand magnifier. Reading a textbook takes quite a time by this way, which discourages students reading the same textbook several times. Having handouts or summaries printed with enlarged fonts are easy for student to revise what they learned at the school and keep it for following revisions. However, the case for the blind students are much more difficult compared to low vision peers. Although braille books are available for blind students, they take too much space and therefore students cannot carry books with them all the time. On top of it, another problem is the limitations of the braille books in terms of representing figures. In order to overcome this problem, all handouts are designed and printed in two different forms for low vision and blind students. Handouts for blind students are printed in normal typeset for sighted people but in enlarged fonts, and braille as well. The reason for this is that teachers and parents have no access to the braille print. Therefore, they are not able to help students both in classroom or out of classroom. Therefore, if it is printed in both format, everybody can access them. Moreover, printing a tactile figure is also a challenging task for teachers. If you do not have the necessary embosser printing system, the only option is preparing them by hand using a silicone gun. In order to overcome this difficulty an Emprint SpotDot Colour Braille Printer, a braille and colour ink embosser, was used. This printer prints figures with dots as well as in colour for low vision or sighted students. Figure 1 shows the materials printed in this way.

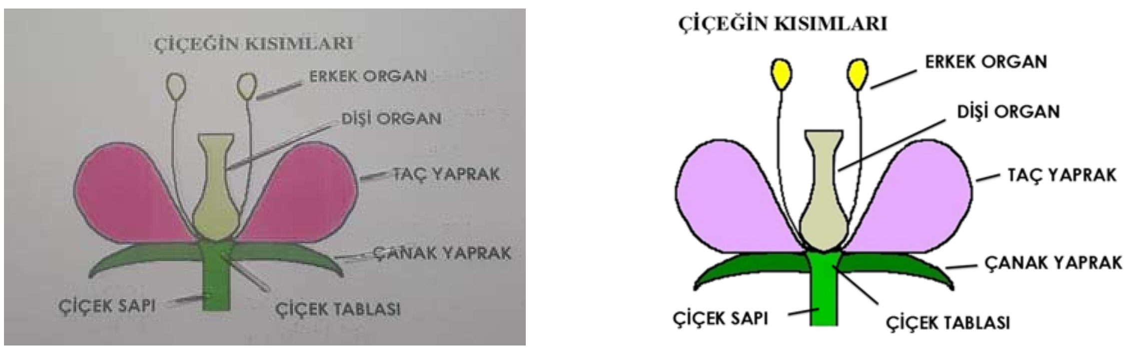

Figure 1. Two types of the same working paper. The one on the left is printed by braille and colour in embosser for blind students, while the one on the right is printed a colour printer for low vision students. Both materials printed in enlarged fonts.

In order to be able to design instructional activities or practical works for visually impaired students, attention has to be given to the use of senses other than vision. In general, the most commonly used sense is hearing in traditional teaching. However, students can benefit from materials that have access through touching is a common practice with visually impaired student. The materials that based on sense of touching are called "tactile materials". In order to develop tactile materials basically two approaches were adopted. The first and easy way is to use current materials for sighted students with some adaptations or develop some with everyday materials. This is particularly important to keep the cost low and make it accessible by everybody. However, it is not easy to make durable materials to teach every single science concept and principles. The second approach is to use the emerging 3D printing technology. This technology is recently developed. Therefore, it is costly and not accessible by everybody. However, it is quite versatile and the materials developed are durable. In order to teach some abstract concepts or re-design the simple materials to the needs of visually impaired students, in this study, 3D materials were designed and printed. Instructional materials developed and printed by 3D technology include models belonged to the concepts cell, reproduction, growth, development, states of matter, transfer of electricity etc.. On the other hand, several models were developed using everyday objects to model the concepts include bulb, fuse, heat, energy transfer, heat transfer etc. The general guidelines followed in designing these materials or practical works are making as much as possible materials to be available for each students in the classroom to give them enough time for investigation. If you do not have enough experimental setting for each student, carrying out practical work takes more time. The second issue is the simplicity of the materials. The majority of the instructional or everyday materials used in practical works includes several different features which have nothing to do with the topics taught. Therefore, these are distracting blind students from understanding the materials through touching. In order to overcome this problem, we have made all materials as simple as possible. It has to include the only features that are important in terms of the particular topic that is intendent to be covered. In addition, it has to be accessible for the low vision student too. For instance, adapting an electric motor runner fan, the blades of the fun were painted with yellow colour to allow low vision student to clearly see. Blind students were used touching to feel the fan running as well as feeling air flow around it. See Figure 2 for sample materials.

Results and discussion

All the materials were trailed with students in the classroom and data were gathered in order to make necessary improvement under the guidance of DBR. Currently, the project is still ongoing. The final aim is to improve the materials according to the needs of students and see their contribution to the students' conceptual learning after the trials. As full data is not collected yet and not analysed, it is difficult to give precise information about their impacts on learning and understanding in science, as well as changes in attitudes and motivation towards science. The observation results show that visually impaired students show interest toward practical work and that they very much like it. Anecdotal evidence from the observers and the teacher indicates that learning, and understanding have been improved. However, there are several drawbacks such as time management due to too much time devoted to the understanding the materials and activities, lack of scientific process skills to carry out the activities and analysing the results and writing reports. It is also difficult to bring students to the idea that all practical activities are aiming to understand a particular science concept, rather than just playing and enjoyment

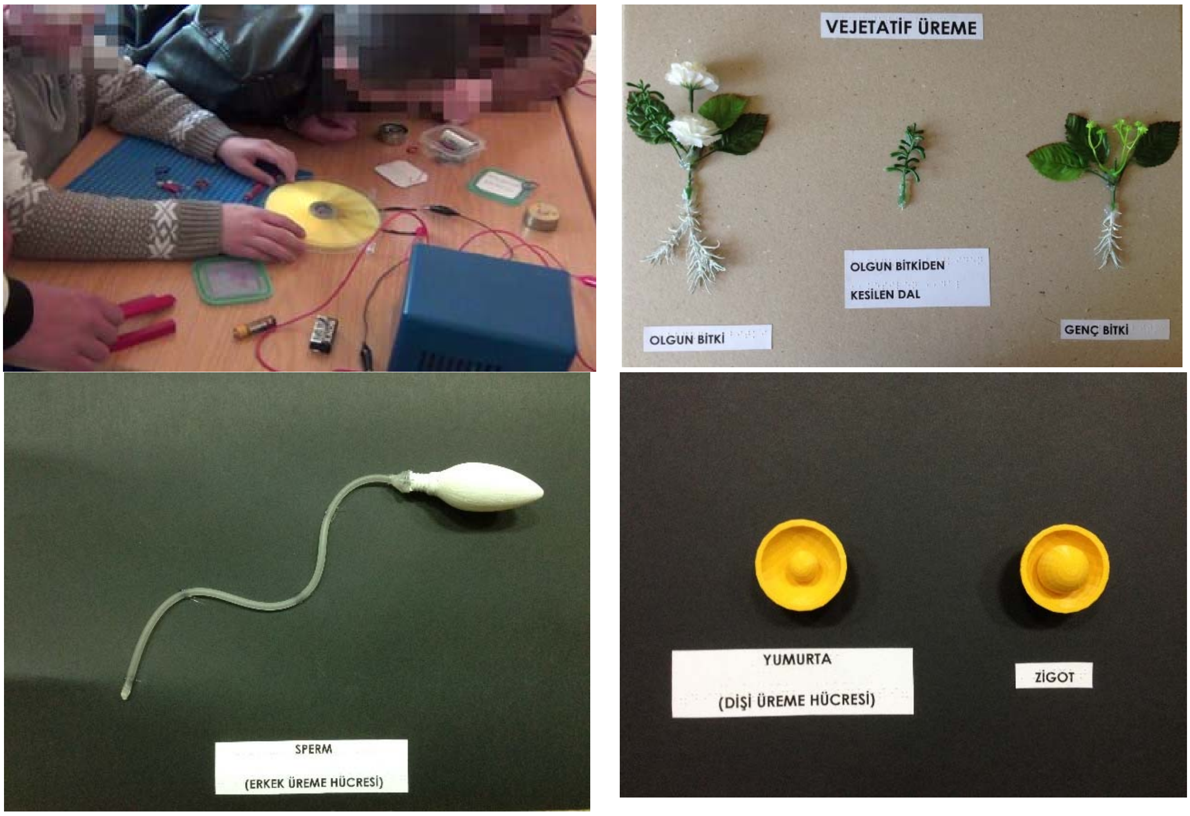

Figure 2. Different types of the adaptation of everyday materials or 3D printed materials. All the materials include features for low vision and blind students.

Conclusion

In order for all students to have equitable opportunities to engage in science there is a need for classroom practices which remedy injustices or provide access to material resources and instructional support. To be able to provide equitable opportunities for visually impaired students, it is clear that the first stage is to understand the needs of individual students with low vision and blindness.

A second important aspect is that designing instructional materials and activities for practical works requires a close collaboration of students, teachers, parents and experts working together in this area. In many cases teachers and parent know the needs but they cannot develop solutions by themselves without support from experts. Therefore, we value working closely together with experts to develop sustainable solutions to the problems.

It is well known from the science education literature that practical work motivates students towards engaging in science, however, it is important to look for ways how this encouragement could be successfully transferred to the areas such as development of critical thinking, problem solving, analysing data, and reporting them. It is also essential to go beyond enjoyment and guide students to learn the scientific content covered in practical work. As visually impaired students are easily distracted by unnecessary details, it is equally essential to design materials and activities to be as simple as possible, as well as focusing on only few core ideas in each practical work, rather than covering several ideas through a single activity.

This study is only carried out in a special school for visually impaired students. The problems faced in inclusive classrooms for visually impaired students is a different topic. As the trends is towards inclusion in special education, more research is needed for the identification of needs of visually impaired students and design criteria.

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References

Abrahams, I. (2009). Does practical work really motivate? A study of the affective value of practical work in secondary school science. *International Journal of Science Education*, *31*, 2335-2353.

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, *30*, 1945-1969,

Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching*, *49*, 1035-1055.

Arter, C., Mason, H. L., McCall, S., McLinden, M., & Stone, J. (1999). *Children with visual impairment in mainstream settings*. London: David Fulton.

Bülbül, M. Ş. (2013). A description of a blind student's science process skills through health physics. *European Journal of Physics Education*, *4*(2), 6-13.

Bülbül, M. Ş. (2014). *The effect of enriched course materials about motion on ninth grade sighted and totally blind students' achievement, motivation, attitude, perception of learning environment and interaction in inclusive classes*. Dissertation, Middle East Technical University, Ankara.

De Azevedo, A. C., Vieira, L. P., Aguiar, C. E., & Santos, A. C. F. (2015). Teaching light reflection and refraction to the blind. *Physics Education*, *50*(1), 15-18.

Design-Based Research Collective (2003). Design-based research: an emerging paradigm for educational inquiry. *Educational Researcher*, *32*, 5-8.

Dion, M., Hoffmann, K., & Matter A. (2000). *Teacher's manual for adapting science experiments for blind and visually impaired students*. www.perkinselearning.org/sites/elearning.perkinsdev1.org /files/teachers-manual.pdf (13/05/2016).

Fraser, W. J., & Maguvhe, M. O. (2008). Teaching life sciences to blind and visually impaired learners. *Journal of Biological Education*, *42*, 84-89.

Hodson, D. (2005). Teaching and learning chemistry in the laboratory: a critical look at the research. *Educación Química*, *16*, 30-38.

Karakoç, T. (2016). *The contribution of guided discovery model of inquiry-based approach to visually impaired students acquisition of experimental procedures, academic success and attitudes towards sciences*. Dissertation, Gazi University, Ankara.

Lewis, A. L. M., & Bodner, G. M. (2013). Chemical reactions: what understanding do students with blindness develop? *Chemistry Education Research and Practice*, *14*, 625-636.

Mastropieri, M. A., & Scruggs, T. E. (1992). Science for students with disabilities. *Review of Educational Research*, *62*, 377-411.

Millar, R. (2010). Practical work. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed.) (pp. 108-134). Glasgow: Open University Press.

National Research Council (2007). *Taking science to school: learning and teaching science in grades K-8*. Committee on Science Learning, Kindergarten Through Eighth Grade (R. A. Duschl, H. A. Schweingruber & A. W. Shouse, Eds.), Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Okcu, B., & Sözbilir, M. (2016). "Let's make an electric motor" activity for 8th grade visually impaired students in "electric in our lives" unit. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi*, *44*(2), 23-48.

Sözbilir, Ö., Gül, Ş., Okcu, B., Yazıcı, F., Kızılaslan, A., Zorluoğlu, S. L., & Atilla, G. (2015). Trends in research papers about teaching science to visually impaired students. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, *15*(1), 218-241.

Supalo, C., & Bodner, G. M. (2012). Increasing diversity by finding ways to teach chemistry to the visually impaired. In S. Markic, I. Eilks, D. DiFuccia, & B. Ralle (Eds). *Issues of heterogeneity and cultural diversity in science education and science education research* (pp.155-162). Aachen: Shaker.

Wild, T. A., Hilson, M. P., & Hobson, S. M. (2013). The conceptual understanding of sound by students with visual impairments. *Journal of Visual Impairment & Blindness*, *107*, 107-116.