ORIGINAL ARTICLE

Barrier-Free Science Education for Visually Impaired Students: An Activity for Life Cycle in Plants

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***Abstract**: This research aims to design and apply a lesson plan to satisfy 3rd-grade inclusive education students' individual learning needs on the subject of plant life cycle, and to develop three instruction materials based on this lesson plan. In the first stage of this three-staged research, visually impaired students' individual learning needs were determined by conducting workshops with science teachers, elementary school teachers, and special education teachers. Then, the learning outcomes of science education programs were determined. In the second stage, teaching materials suitable for students' personal characteristics were designed by the teachers after assessing the students' needs. Visually impaired students also participated in the process of developing the educational material. In the last stage, students were taught according to the lesson plan with the materials prepared according to the 5E learning model. After the lessons, data were collected through semi-structured interview forms to determine the students' opinions on the lessons and materials. Descriptive analysis was used to analyze the qualitative data obtained. The research results showed that the teaching material responded to the needs of the students and contributed positively to their conceptual learning.*

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Introduction

THE limitations of sight cause the students to encounter a lot of problems in access to basic education. Visually impaired students (partially sighted, blind) have difficulty accessing especially such lessons as science in which the visual content is intense in quantity (Jones et al. 2012). Previous research shows that visually impaired students have difficulty in learning subjects of science education where visual elements and abstract concepts are emphasized (Kalaycı 2001; Okcu, Yazıcı, & Sözbilir 2016), and they have less competence on the basic concepts than their sighted peers (Darrah 2013; Kolitsky 2014). For this reason, visually impaired students need different teaching strategies (Weems, 1977; Ataman 2012; Harshman, Bretz, & Yezierski 2013; Atila 2017; Okçu & Sözbilir 2017; Yalçın & Kamalı Arslantaş 2020) and different teaching materials (Atila 2017; Sahin & Yorek 2009; Yalçın 2020; Yalçın & Kamalı Arslantaş 2020) than their sighted peers. Teaching techniques and strategies that respond to individual characteristics and learning channels (sight, hearing, and touch) should be chosen for satisfying the needs of visually impaired students. Also, science concepts should be materialized as much as possible with suitable activities and materials (Cavkaytar & Diken 2012; Dion, Hoffman, & Matter 2000).

Tools such as a barometer, embossed thermometer, experiment tools with Braille labels, human figures, three-dimensional materials and models, three dimensional cells and DNA models, or tactile anatomy atlas should be procured for visually impaired students for their science lessons. Moreover, producing tactile drawings, using hot silicone to draw figures on Braille paper (Supalo 2005), embossed rulers or assistant technological devices (Kumar, Ramasamy, & Stefanich 2001), forming tactile models, preparing embossed maps (Sahin & Yorek 2009), animals and plants, models of organs such as heart, kidney, or stomach, human and animal skeletons, and all other devices adjusted for the visually impaired students can be helpful in science lessons (Köseler 2012; Yazıcı, Gül, & Sözbilir 2016; Zorluoğlu & Sözbilir 2016). For partially sighted students, it is advised to use physical objects and materials designed with large fonts and contrasting colors (Altunay Arslantekin 2018; Yalçın 2020). Also, assistant technological devices (3D Printer, 3D Pen, screen readers, magnifiers, etc.) are used effectively in both the visually impaired and partially sighted students' access to the lessons (Aslan 2016).

Previous research suggests the effectiveness of course materials prepared according to the needs of visually impaired students. For example, Zorluoğlu and Sözbilir (2017) designed materials suitable for the needs of visually impaired students in learning, and applied them on teaching the concept of intensity, Kızılaslan and Sözbilir (2017) on teaching heat and temperature, Lewis and Bodner (2013) and Boyd-Kimball (2012) on teaching chemistry, Smothers and Goldston (2010) on phase transition, Yazıcı and Sözbilir (2020) on teaching the concepts of the respiratory system, Supalo and Kennedy (2014) on the topics of organic chemistry, Gupta and Singh (1998) on the subject of heat exchange and temperature measurement, and Yazıcı and Sözbilir (2020) on support and movement system. All of the researches reported that visually impaired students had similar learning characteristics with their sighted peers when materials were developed in a way that could appeal to their learning channels.

This research aimed to design and apply a lesson plan that responds to the needs of visually impaired 3rd grade students in an inclusive class for individual learning on the subject of the plant life cycle in science lesson, and to develop three teaching materials within this lesson plan in order to enable the access of visually impaired students to science lessons and to help with the difficulties they experience.

The Activity

Lesson

Grade level: 3
Lesson time: Three 45-min periods recommended.

Purpose

At the end of the course, it is aimed to achieve the following objectives;

- The students monitor the growth of a plant for a certain period of time.
- The students explain the phases of a plant's life cycle.
- The students record the results of a plant's life cycle.

Safety

The use of cutting tools should be under the guidance of the teacher.

Procedure

The 5E Instructional model was used to plan the research lesson. The teacher was a facilitator, guiding the student through questions, investigations, experiences, and research. The 5E Instructional Model can be used to design a science lesson, and is based upon cognitive psychology, constructivist-learning theory, and best practices in science teaching (Bybee & Landes 1990). The cycle consists of cognitive stages of learning that comprise engage, explore, explain, elaborate, and evaluate. The 5E instruction model was developed originally for the Universal Design for Learning (UDL). UDL is an approach to teaching aimed at meeting the needs of every student in a classroom that helps give all students an equal opportunity to succeed. At its core, UDL means that a teacher designs learning experiences to remove any barriers to learning and give all students equal opportunities to succeed. UDL suggests giving students more than one way to interact with the activity material and to understand why they should learn what they're learning (Morin 2014).

The fundamental principles paid attention to in the research while developing/adjusting the teaching materials for the students' needs are listed below,

- Materials should be relevant to the learning outcomes.
- Materials should be prepared in a way that helps students objectify abstract concepts.
- All of the materials should be prepared in visual and tactile formats. So, the materials should address more than one learning channel while they are being prepared.
- The writings on the materials should be in large fonts for partially sighted students and in Braille format for visually impaired students.
- Especially for the visually impaired students, materials that are tacitly distinguishable should be used (e.g., foam or sand).
- During the development process, color and background contrast for partially sighted students should be a priority.
- High (e.g., 3D Printer) and low (e.g., Braille tablet) technological tools that have highly been preferred for visually impaired students' access to knowledge in recent years should be made use of during the process.

5E Instructional model lesson plan and the development process of teaching materials in this study is detailed below.

Engage

At this stage, students are made to read the story below (Braille, large font) that would attract their attention to the topic. Students are then asked to answer questions related to the story. At the beginning of the lesson, students are expected to realize the living things and inanimate objects around them and establish a relationship between their life cycle and everyday life.

> *Ece goes to her grandmother's village with her family every summer. Sunflower fields capture her attention as they approach the village. The yellow color of the sunflowers looks fabulous. Her dad tells her that another name for sunflower is day viewer. The birds and colorful butterflies flying over the sunflower fields*

look incredibly beautiful. When her dad asks Ece if she knows "the sunflowers follow the Sun," Ece gets surprised and grows curious. On the road, her dad gives her this information. Many people may think of plants as inanimate since they do not move. Actually, plants are alive, and they can move to a certain extent. The sunflowers that follow the Sun during the day are the best example of this phenomenon. The flowers of sunflowers move from the east to the west by following the Sun during the day. At night, they move in the opposite direction and go back to their position in the morning. This daily movement is observed in the developing sunflowers, and it ceases when they become ripe. Ece is very surprised when she hears this information, and she starts to think about the properties of living things. She also thinks if she has seen non-living things on the road. The stream in their village, fruit trees, mountains, bird nests, her grandfather's cows, etc. Ece's mind is thoroughly confused.

- -What are the living and non-living beings in the story?
- -Can living and non-living beings have common properties?
- -What are the properties of living beings?
- -What are the properties of non-living beings?
- -How does the life cycle of sunflower begin?
- -How do you think a seed becomes a plant?

Explore

In this stage, a course material named "Plant Life Cycle Calendar" is prepared by considering sighted, partially sighted, and visually impaired students' learning channels. Below are the materials and the development process for the course material named "Plant Life Cycle Calendar".

Used Materials: Cardboard, metal ring, colored construction paper and felt, glue, Braille tablet, nail, printer, utility knife

Development Process: 5 cardboards are cut in A5 size. On the first cardboard, a figure representing the seed is made from construction paper and felt. On the second and third cardboard, figures representing germination are made of construction paper and felt. A round plant on the fourth cardboard is prepared from construction paper and felt, and a mature plant on the fifth one. Then the internal mechanism of the cardboard desk calendar is prepared. The cardboards are conjoined; we open two holes on their top and pass the metal rings from these holes. The cycles' names are written on acetate paper in Braille with large fonts, and they are glued on the appropriate places on top

Figure 1. Steps by Teachers in Developing the Material.

of each cardboard. Photos of the steps for the development of teaching materials are shown below (**Figure 1; Figure 2).**

The Application of the Material: Each student gets to examine the calendar. It is examined holistically by the visually impaired student. Next, the student is informed about it. Then, the student is asked to study the calendar pages one by one by touch/look. It is necessary to give elaborate descriptions while informing the students after they examine the calendar. Afterward, visually impaired students should be made to touch the calendar while it is being exhibited to sighted students. The current situation is discussed through question-answer technique.

Explain

The students are informed about plant life cycle in this stage. Then, within an extent that is appropriate for the students' age group and their capacity of observing their surroundings, they are told that the plants have a life cycle like the other living things, and that a plant's life cycle begins with pollination. They are also informed about the insects' role in pollination, and further phases of this life cycle such as insemination, zygote, embryo development, growth and a mature plant. Phases start with the seed for this age group.

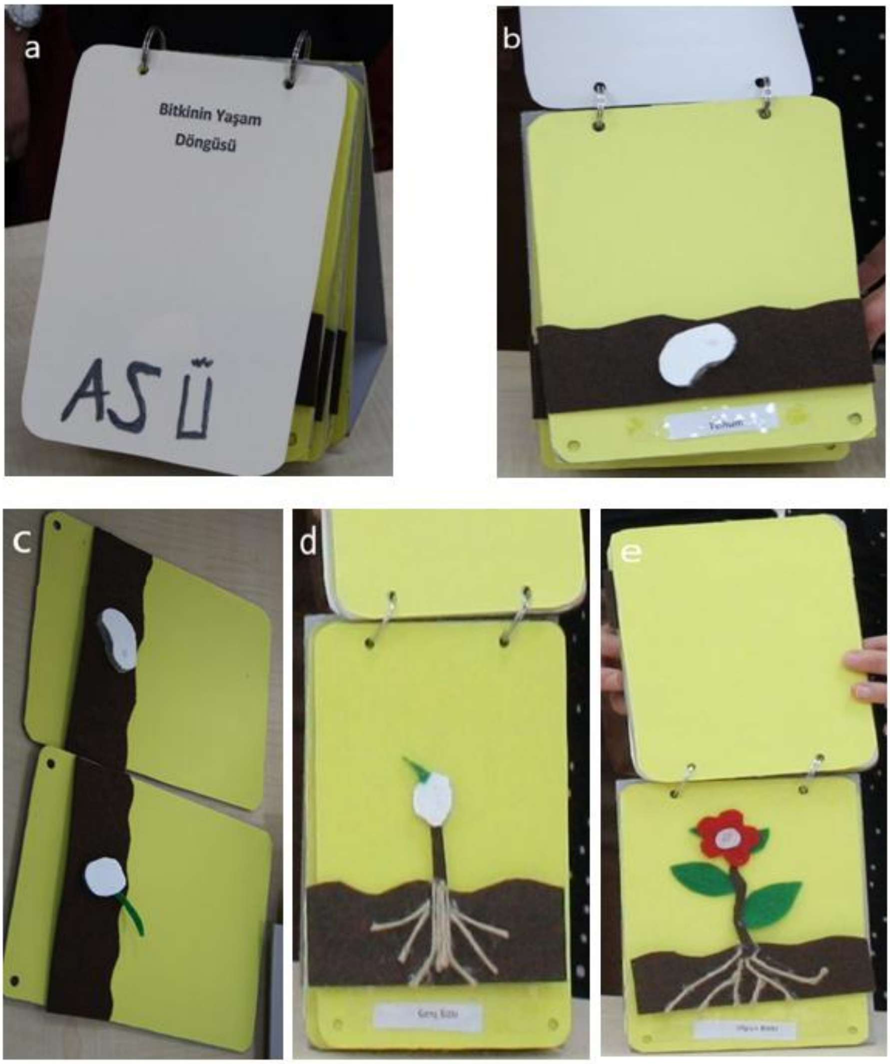

Figure 2. Calendar Pages for the Life Cycle of the Plant.

Elaborate

At this stage, students are informed about the design of the 'Plants Grow' material below. It aims to deepen the students' knowledge which they acquired during the lesson. The stages of this activity are presented below.

Figure 3. Preparation Stages of the “Plants Grow” Material by the Teachers.

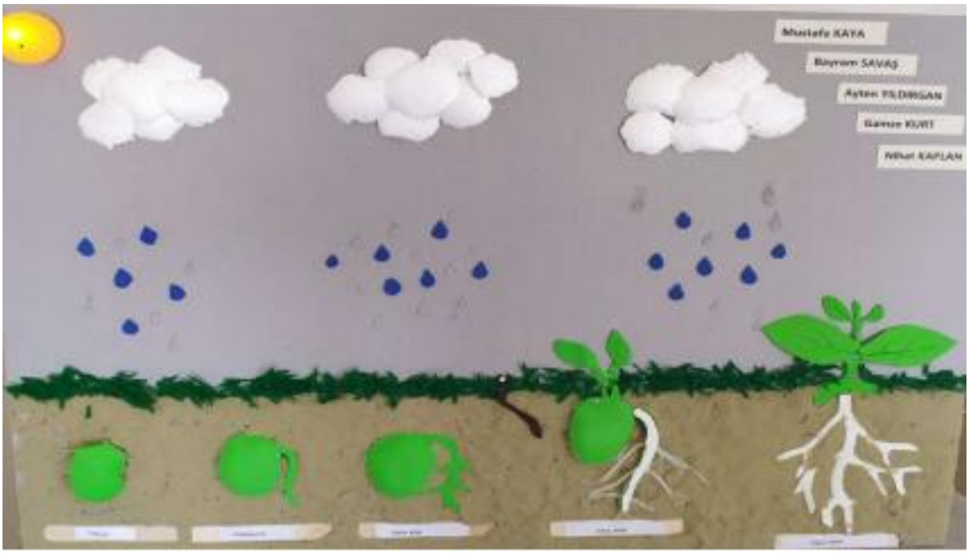

Figure 4. “Plants Grow” Material.

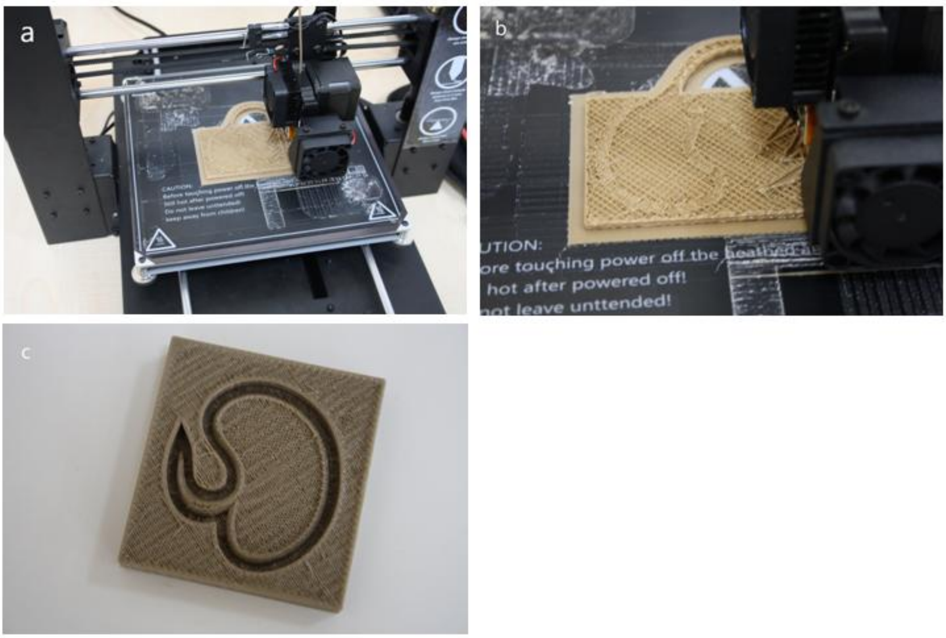

Figure 5. Steps of 3D Printing of Teaching Materials.

Used Materials: Cardboard, foam/cotton, sand/soil, green construction paper and felt, white construction *paper*, glue, hot silicone and silicone gun, transparent glue, blue ink, ping pong ball, connection wires, socket, battery, light bulb.

Development Process: The soil is glued on the bottom of the cardboard. On the top, clouds made of foam are glued to an appropriate place. Raindrops made of transparent glue and blue ink are positioned below the clouds. Above the soil, grass made of felt is glued. Figures representing each phase of the plant's growth process are made from colored construction papers and glued above the grass. The figures made from colored construction paper are stuffed with cotton and glued. The visuals about the plant's life cycle are glued on the cardboard. Under each figure narrating the process of plant growth, the phase's name is written in Braille and large font format and glued. Photos of the steps for the development of teaching materials are shown below (**Figure 3; Figure 4**).

The Material's Application: The visually impaired student is made to examine the material holistically at first. Then, the student is made to touch every object in the material. The student is informed about what the object the student is touching/looking at represents.

Evaluation

Materials comprising each phase of the bean plant's life cycle printed by a 3D printer are distributed to the students. The students are asked to examine these materials. Then, the teacher hands over the students one of the materials representing plant life cycle and makes them touch it, and asks them to tell which phase of the cycle (seed, germination, young plant, etc.) the material represents. The teacher evaluates the students' knowledge about the topic by initiating an in-class discussion. Photos of the steps for the development of teaching 3D materials are shown below (**Figure 5; Figure 6**).

"Life Cycle" activity that can be seen below is practiced together with the students in class. Their lack of knowledge about the topic is eliminated. As seen in the visual, the cycle can be printed on a Swell paper and be embossed by using a Piaf machine.

Activity's Name: Life Cycle

Like all other living things, plants also have a life cycle. Below is given the tomato plant's life cycle (**Figure 7**). Fill in the boxes with the name of the event realizing in each phase

On the visual above (**Figure 8**), an example is provided in the Braille format in order to show the names of the phases in the plant's life cycle.

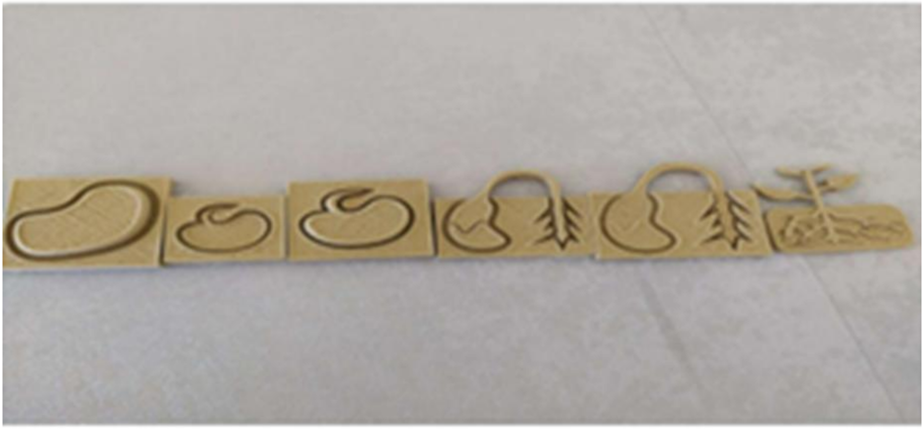

Figure 6. 3D Model of the Plant's Life Cycle.

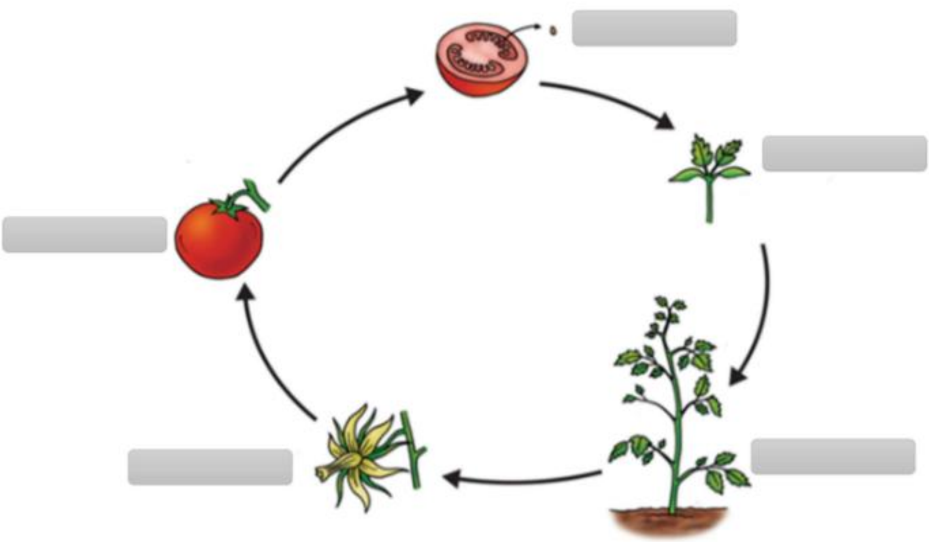

Figure 7. Tomato Plant'S Life Cycle.

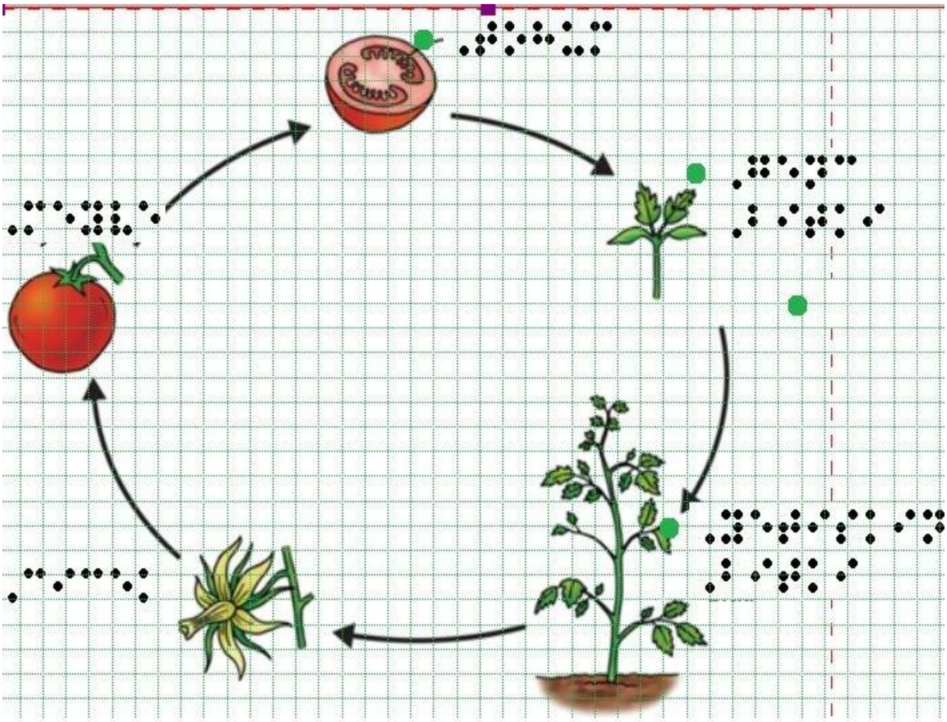

Figure 8: The Names of the Stages of the Plant's Life Cycle, Written in Barille Format.

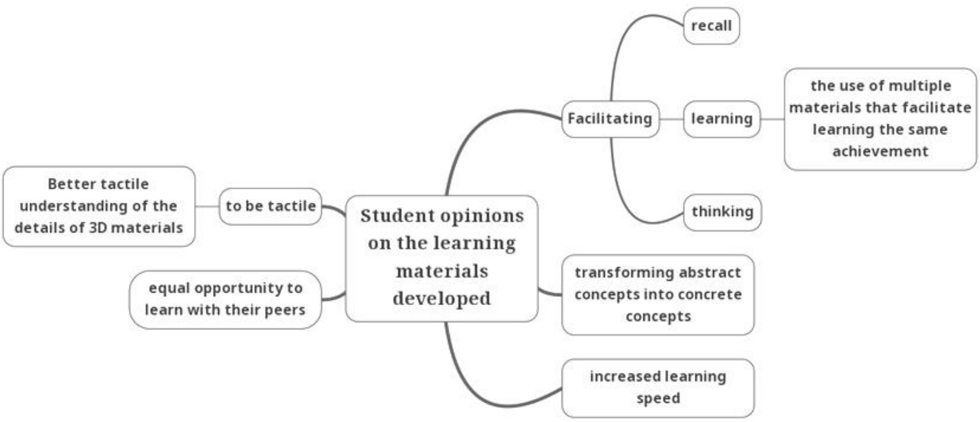

Figure 9: Mind Map of Student Opinions.

Reflection and Implications for Teaching and Learning

The activities and teaching materials developed in this article were developed within the scope of the Barrier-Free Science Teaching Project supported by the Sabancı Foundation. The teaching materials and activities developed in the project were prepared in order to enable students studying in inclusive classrooms to learn science concepts better. In the related project, inclusive classroom teachers, science teachers and special education teachers and visually impaired students worked together in the development of teaching materials. In the province where the research was conducted, the number of visually impaired students studying in the inclusion class is limited. The project was carried out during the Covid 19 pandemic period. For this reason, the opinions of two visually impaired students studying in the inclusive classroom, who actively participated in the development of the teaching materials (in the pilot phase and in the application process), were consulted.

In this research, a lesson plan that responds to the needs of 3rd grade visually impaired students in an inclusive class for individual learning on the subject of the plant's life cycle in science lesson was designed and applied, and three models were developed based on this lesson plan. A teaching session with two visually impaired students was administered after this stage. Students were made to use the developed teaching materials. Then, a semi-structured interview form, composed of six open-ended questions, was used to collect the students' opinions on the lesson plan and materials. The students' responses to the open-ended questions were coded and presented as S1 and S2.

It is necessary to use more than one material in order to achieve the learning outcomes. Teaching should be rich in materials, especially to objectify abstract concepts for visually impaired students.

S1 stated: "*Teaching in this way was fluent, efficient, and clear. The existence of more than one material, the preparation of tactile materials, and the presentation of detailed information in an order were effective for me*."

It is observed that if the concepts of science were taught with these processes from the beginning of the pre-school period, the visually impaired students would have a better basic knowledge level on which new knowledge can be developed better. According to the 5E learning model, which is one of the constructivist approaches, students construct new knowledge based on their prior knowledge. S1: "*I would definitely learn much better, and I would have a sound background. It would be easier to keep in mind, recall, and learn. I was able to learn such concepts as earthquake, landforms, formation of the continents much easier*." S2: "*I could also learn* *about pyramids and old buildings with these materials."* With these statements, the students expressed that visually impaired students will have a better basic knowledge level.

Research findings in the literature show that visually impaired students have limited exposure to course materials and materials suitable for their needs in concept learning (Bargerhuff, 2013; Yazıcı & Sözbilir, 2020). It is necessary to design audio, tactile, large font or Braille documents suitable for the needs of visually impaired students and to include all these materials in classroom activities (Yazıcı, Gül, Sözbilir, Çakmaka & Aslan, 2021). If this need is met, visually impaired students can learn the concepts in science and other visual lessons better, and their incomplete and erroneous learning can be prevented.

The use of assistant technologies in the education of visually impaired students is accelerating. Using technological tools in teaching materials is just as important as teaching the students how to use these tools in their access to the materials. Students S1 and S2 stated: "*I liked both the materials made by our teacher and those printed by 3D printer. Even the smallest details were there in the printed material*." The students stated that the use of technology would increase their learning pace.

This finding shows that visually impaired students are aware of assistive technological tools, which are accepted as a facilitating tool in accessing information. Studies in the literature state that assistive technological tools are an important element that facilitates both the academic and daily lives of visually impaired students (Aslan, 2016; Yalcin & Kamali Arslantas, 2020; Yalçın & Altunay, 2021; Thurlow, Johnstone, Timmons & Altman, 2009). Therefore, especially the courses where visual content is intensive, the use of assistive technological tools in all courses and extracurricular activities is expected to be widespread.

The difference in the textures of materials used in the development of tactile materials increases their discernibility. For example, S1 stated: "*The seed's germination is explained by sand, and another by construction paper. I did not confuse the topics; recalling and learning became easier*."

The teacher's use of concrete materials while teaching the topics during class enables the students to have an answer for their questions by themselves. For example, S1 stated: "The topic is explained as well as the material is used. It eliminates the question concerning how the seed germinates."

Inclusive education supports equal opportunity for all individuals. But in Turkey, the difficulties experienced in educational support services of inclusion and teachers' lack of knowledge on inclusion prevent equal opportunity in education. For example, S2 states: "*We are learning what our sighted peers actually learned in the 3rd grade in the 5th grade. With this type of materials, we could have learned concurrently with our sighted peers at an earlier stage*."

As a matter of fact, studies in the literature have reported that preparing materials suitable for students' own learning channels facilitates their learning processes (Kızılaslan & Sözbilir, 2017; Okcu & Sözbilir, 2016; Yalçın, 2022). In a study conducted by Yalçın (2022), the opinions of students, teachers and families about tactile materials prepared for visually impaired students to be used in science lessons were determined. As a result of the study, it was seen that all three groups stated that the materials prepared would have a positive effect on the learning processes of the students.

In the mind map below (Figure 9), the views of the visually impaired students participating in the research on the 5E learning model developed within the scope of this project and the teaching materials developed are presented as a whole.

Considering the data collected from the responses (as shown in Figure 9), findings of this research put forward the importance of using teaching materials and lessons planned according to 5E learning model through objectifying the abstract information in the education of visually impaired students, increasing their learning pace, facilitating thinking, increasing permanence, compensating for the missing prior knowledge, and equal learning opportunity with their peers.

Studies show that the 5E method within the scope of the constructivist approach is also an effective method that can be used to improve science literacy (Ayvacı & Bakırcı, 2012; Dikici, Türker & Özdemir, 2010). Therefore, although these findings obtained from students were obtained from a limited number of visually impaired students, it is thought that they will shed light on educators in teaching science concepts to students with special needs.

Conclusion

Visually impaired students are in a disadvantaged position in terms of access to lessons such as science, which is intense in visuals and includes abstract concepts, due to their limitations in seeing. It is, therefore, necessary to teach with materials that can objectify the abstract concepts in order to obviate visually impaired students' difficulties in learning science and to help them learn the concepts. In other words, it is necessary to make use of audial, tactile, and visual material proper to the learning channels of visually impaired students, to use effective learning strategies in a class environment, and to make specific arrangements in a setting suitable for the student's needs in inclusive classrooms. Lastly, the use of assistant technological tools to adjust the materials and preparation of course books according to the students' needs is critical for students' access to lessons.

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APPENDIX I

Interview Questions

1. *What was your favorite material in this work? Why is that?*
2. *Have you had any new information you haven't learned in the past but learned while using these materials?*
3. *Do you like the teaching and lecture according to the 5E learning model? Why is that?*
4. *What kind of differences do you think would be about your own learning if all your lessons were taught in this way and such materials were used?*
5. *Would you suggest that we do lessons with your friends who are visually impaired with these kinds of materials? Why is that?*
6. *Do you have any different suggestions regarding the study, especially the materials?*

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