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Teaching Cell to 6th Grade Students with Visual Impairment *

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Abstract

In this study, the design process of a model for the teaching of science concepts related to the 'cell' subject in 6th grade students with visual impairment (SVI) was discussed and the effectiveness of this design was evaluated from various aspects. Design Based Research method was used in this research which is based on ADDIE model for instructional design. In the first stage of the three-stage instructional design, the individual learning needs of the six SVI and their levels of learning the basic concepts in the 'cell' subject were determined. In the second stage, the teaching materials and activities were designed in accordance with the determined needs and the designed teaching model was tested on nine SVI in 6th grade. In the last stage, the instructional design was evaluated in terms of applicability, usefulness and contribution to concept learning. Semi-structured observation and interview forms were used as data collection tools and the obtained qualitative data were analyzed by using descriptive analysis approach. As a result of the study, it was determined that the teaching model designed in accordance with the determined needs contribute the students to learn the concepts of 'Cell' subject effectively and to reach the related acquirements.

Keywords

Visual impairment
Concept learning
Design based research
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Cell

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Introduction

The eye is the most important sensory organ that allows easy and very rich information from the environment (Ataman, 2003). Students who experience any deficiency or loss of their vision face problems in areas such as language development, classification and perception of perspective (Mann, 2006). Therefore, this situation disrupts the learning process and negatively affects the development of daily life skills (Cavkaytar & Diken, 2012). Visually impaired students who have more difficulties particularly in science lessons that particularly rely on visual senses due to its content need activities in which they can use their different senses by using concrete objects, tactile models and Braille notes, and learn by first hand experiences in learning environments suitable for their visual impairment (Ataman, 2012; Gürsel, 2012; Harshman, Bretz, & Yezierski, 2013; Kalaycı, 2001; Koenig & Holbrook, 2000; Lowenfeld, 1974; Okcu, Yazıcı, & Sözbilir, 2016; Sözbilir et al., 2015; Tuncer, 2011). Since most of the students with visual impairment (SVI) do not meet these needs, they experience access barriers to science classes, perform poorly science and laboratory studies, their motivation levels and attendance to lessons are low, and they develop many misconceptions about the subjects (Bell & Silverman, 2019; Gül, Yazıcı, & Sözbilir, 2016). It is thought that appropriate learning/teaching environment as well as materials for these students cannot be provided for various reasons such as negative attitudes, budget and policy-related problems, insensitivity to their problems encountered and disbelief that they can be successful (Akakandelwa & Munsanje, 2011; Crosby, 1981). Whereas, when students are included in learning processes created in accordance with their individual needs and disability situations, and when they are given more time, opportunities of doing activities, and various learning experiences, they can develop their cognitive skills, conceptual learning and achieve educational acquirements (Cavkaytar & Diken, 2012; Kızılaslan & Zorluoğlu, 2019; Sunal & Sunal, 2003; Topsakal, 2005). The learning process created for SVI differs according to the visual level of these students. While it is developed for blind students the activities and materials that enable particularly using senses of hearing and touch except for sense of sight, for students with low vision, a number of arrangements are made such as font size, object size, color/contrast adjustments supporting the use of their residual vision (Boyd Kimball, 2012; Flair & Setzer, 1990; Neely, 2007; Sözbilir & Okcu, 2019; Willings, 2017).

Science education has an important role for individuals to can produce scientific solutions to the problems they face in daily life through developing of scientific thinking and problem solving skills (Cawley, 1994; Dimopoulos & Koulaidi, 2003). All individuals in the learning process should gain the knowledge, skills and attitudes related to science in order to increase the quality of their life. As biology subjects in science courses are closely related to daily life, creatures and nature. The teaching of these subjects to students is considered important in terms of recognizing themselves and their environment. However, according to Chuang and Cheng (2003) and Yip (1998); biology subjects come at the beginning of the science course where students have difficulty in understanding, failing and developing misconceptions. Considering the research of misconceptions about biology subjects, it is seen that students have quite misconceptions particularly about cell and cell division (Akyürek & Afacan, 2013; Atılboz, 2004; Dreyfus & Jungwirth, 1988; Flores, Tovar, & Gallegos, 2003; Sesli & Kara, 2012; Yeşilyurt & Gül, 2012; Yılmaz, Tekkaya, Geban, & Özden, 1998). Whereas, it is important for students to learn basic concepts about cell subject because it makes them understand the more complex subjects such as embryonic development, genetic and biological systems. On the other hand, cell biology and events occurring in the cell are quite abstract subjects and are difficult to be understood by students because these subjects contain microscopic structures and processes at molecular level. Therefore, in the teaching of such subjects, several teaching materials should be designed with the help of constructivist approach, experiments/applications should be made by using various tangible experimental equipments and course materials to provide students with rich experiences (Saygın, Atılboz, & Salman, 2006).

SVI are at a disadvantage compared to their sighted peers due to lack of their visual perception, particularly in biology subjects where visual sense is used more frequently. Sighted students describe biology subjects as complicated because these subjects are difficult to understand and they contain broad and abstract subjects. Besides, biology subjects are much more difficult and complex for SVI who partially or totally lose sense of visual. For this reason, in teaching biology subjects, it should be ensured that sighted students use their visual sense more and that SVI use both their visual sense and other senses, too. In the courses that biology subjects are taught, tangible instructional materials in accordance with SVI's individual learning needs and visual perception levels should be designed. In addition, these students should be given opportunities to practice/experiment using these materials and should be able to construct information by themselves through active learnings. However, in the literature, there are few studies focusing on this need on biology subjects (Cooperman, 1980; Fraser & Maguvhe, 2008; Kumar, Ramasamy, & Stefanich, 2001), and any studies has not been encountered with teaching of the cell subject to SVI at secondary school.

Research Purpose

The aim of this study is to design a model for teaching the concepts of cell subject in science course to 6th grade SVI and to evaluate the usefulness of this model and its effect on concept learning. As mentioned above, the conceptual understanding of the cell subject is important in terms of the students' understanding of more complex subjects such as embryonic development, genetic and biological systems. Therefore, such scientific studies are needed in terms of providing conceptual learning. In addition, cell biology and events occurring in the cell are abstract subjects, and are difficult to understand because they contain microscopic structures and processes at the molecular level. Studies on development and use of methods/techniques and/or teaching materials for effectively teach such abstract subjects to SVI is also important in terms of production of knowledge based on scientific data. It is thought that this study can contribute to the literature and practice in terms of both aspects mentioned above.

Research Questions

The following research questions were answered in parallel with the purpose of the research;

- What are the learning levels and needs of 6th grade SVI regarding the basic concepts of cell subject in science course?
- What should be considered while designing and using activities/materials related to teaching of the basic concepts about cell subject in science course to 6th grade SVI?
- What are the effects of developed instructional design for teaching of the basic concepts about cell subject in science course to 6th grade SVI on concept learning?

Assumptions and Limitations

In 2014-2015 and 2015-2016 academic year, whole 15 SVI studying in 6th grade of the Secondary School for The Visually Impaired in Erzurum were included in the research. Although working with all 6th grade students at school, due to small number of students available, the generalizability of the research is limited. In addition, it was assumed that 6 students in needs analysis group (2014-2015 academic year) and 9 students in implementation group (2015-2016 academic year) were similar to each other in terms of learning skills, readiness and level of disability. Also, this research is limited to the acquirements about 'Cell' subject in 6th grade Science course.

Method

Research Model

In this study based on Design Based Research method, ADDIE model was used for instructional design and 3 main stages were followed. In the first stage of the research (Analysis), the individual needs of SVI about science learning and the level of understanding the basic concepts related to Cell subject were determined. Subsequently, in the second stage (Design, Development and Implementation), teaching materials and activities that can meet the determined needs were designed, developed and implemented in classroom. In the last stage (Evaluation), the applicability of the instructional design and its effect on academic achievement were examined in detail. In research using design-based research method, the situation in which learners are found is analyzed, a learning environment that compatible with these analyzes and that contributing to the success of the learners is created. In addition, through taking into consideration the principles of learning/teaching and designing teaching materials and activities, an answer to a particular learning-teaching problem is sought. Briefly, design-based research contains processes that planning, designing and evaluation of instruction. Thus, instruction is provided to be more effective (Akkoyunlu, Altun, & Yılmaz Soylu, 2008).

Participants

The study group consisted of 15 SVI studying in 6th grade of the School for the Visually Impaired in the center of Erzurum, a city in the east of Turkey. It was studied with six students during the analysis phase, (2014-2015 academic year) and studied with nine students in the implementation phase (2015-2016 academic year). The characteristics of these students in the study group according to GFVAI-Gazi Functional Vision Assessment Instrument (GFVAI's description was made in the section of data collection tools) are given in Table 1. Purposeful sampling method was used to constitute the study group. Purposeful sampling method; it is a sampling method that provides rich data fit for purpose of research and provides an in-depth explanation of facts and events (Patton, 2002).

Table 1. Characteristics of The Participants According to The GFVAI Assessment Results

	Student	Gender	Age	Level of vision	Visual skills	Reading skills
Group of needs analysis (2014-2015)	$S_{A.1}$	Female	12	Low vision	Reaction to 10x10 cm of sizes images from 1 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$S_{A.2}$	Male	13	Blind	Perceiving tactile materials.	Printed in Braille.
	$S_{A.3}$	Female	12	Blind	Perceiving tactile materials.	Printed in Braille.
	$S_{A.4}$	Female	12	Low vision	Reaction to 10x10 cm of sizes images from 3 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$S_{A.5}$	Female	17	Low vision	Reaction to 10x10 cm of sizes images from 2 m distance.	Essays from 10 cm distance written with century gothic font and double space.
	$S_{A.6}$	Male	13	Low vision	Reaction to 10x10 cm of sizes images from 1 m distance.	Essays from 15 cm distance written with century gothic font and double space.

Table 1. Continued

	Student	Gender	Age	Level of vision	Visual skills	Reading skills
Group of implementation (2015-2016)	$S_{I.1}$	Male	11	Low vision	Reaction to 10x10 cm of sizes images from 3 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$S_{I.2}$	Male	12	Low vision	Reaction to 10x10 cm of sizes images from 1 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$S_{I.3}$	Male	12	Low vision	Reaction to 10x10 cm of sizes images from 2 m distance.	Essays from 10 cm distance written with century gothic font and double space.
	$S_{I.4}$	Female	12	Low vision	Reaction to 10x10 cm of sizes images from 3 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$S_{I.5}$	Male	13	Blind	Perceiving tactile materials.	Printed in Braille.
	$S_{I.6}$	Female	12	Blind	Perceiving tactile materials.	Printed in Braille.
	$S_{I.7}$	Male	12	Low vision	Reaction to 10x10 cm of sizes images from 2 m distance.	Essays from 15 cm distance written with century gothic font and double space.
	$Ö_{I.8}$	Male	12	Blind	Perceiving tactile materials.	Printed in Braille.
	$Ö_{I.9}$	Female	16	Blind	Perceiving tactile materials.	Printed in Braille.

Data Collection Tools

During the data collection, semi-structured observations and semi-structured individual/focus group interviews were conducted. The first of two observation forms developed by the researcher (Yazıcı, 2017), The Science Course Observation Form (SCOF) was used in the analysis phase (first phase) to determine individual learning needs of the students and their problems encountered concerning science course. The second observation form, the Science Activity Observation Form (SAOF) was employed during the implementation and evaluation phases (second and third phases) in order to evaluate the designed/implemented teaching model from various aspects. In interviews, during the analysis phase (first phase), semi-structured individual/focus group interview forms were prepared and used in order to determine conceptual learning level related to subject at the end of the current instruction and individual learning needs and problems of teachers/students in science teaching/learning. In individual interviews with students, it was aimed to determine conceptual learning levels of SVI regarding the concepts of 'Cell' subject, and in focus group interviews, it was aimed to reveal problems and needs in science courses particularly on 'Cell subject'. In individual interviews with science teachers, teachers' opinions were taken about problems experienced during teaching process and needs on teaching of cell and other science subjects. Also individual/focus group interview forms were created and used in implementation and evaluation phases (second and third phases) to get the opinions of teachers and students about implemented instructional design and to determine the contribution of design to concept learning. In individual interviews with the students, learning level of concepts about 'cell' subject was tried to be determined. In individual interviews with teacher who is implementer of the design and focus group interviews with students of application group, opinions and suggestions were taken about instructional design's strengths and weaknesses, usefulness, applicability, functionality, contribution of learning subject and concepts. Moreover, the functional vision of each student in implementation group where the design will be applied were evaluated through using Gazi Functional Vision Assessment Instrument (GFVAI) (Şafak, Çakmak, Kan, & O'Dwyer, 2013). Thus, it is aimed that instruction model is appropriate for individual characteristics of the students by revealing how the students use their visual sense through different materials in real life and that provide effective learning of the concepts related to the subject. In addition, the Teacher's Guidebook Expert Opinion Form (TGEOF) was also prepared and used in order to present teacher's guidebook to experts before the implementation.

Data Analysis

Qualitative data obtained from this research were analyzed by descriptive analysis approach. Researcher made classroom observations through prepared observation forms and recorded all observations via video camera. After classroom observations are completed, researcher made observations again by watching all the video recordings. In addition, an expert made observations through watching videos that chosen randomly and using observation forms. Finally, the results of both observations made by the researcher and the observations of the expert were compared to each other and inconsistencies were eliminated and the analysis of the observation data was completed. The semi-structured individual/focus group interviews with teachers and students were recorded in the audio record and were transcribed. Afterwards, all texts were analyzed. In order to determine the level of concept learning, the answers to the open-ended questions in individual interviews with students were analyzed in three categories as exactly correct, partially correct and incorrect answers. In the process of analysis of interviews, the transcripts that chosen randomly were analyzed by an expert and compared with researcher's analysis. A higher level than 80% concordance was found between the two researchers' analyzes. The inconsistencies in this process were eliminated by discussing and the analysis of interview data was finished. Finally, the obtained data were summarized according to the themes in the research questions and data collection tools and were described and interpreted with direct quotations. Thus, it is aimed to present the obtained data to the readers in an edited and interpreted manner. In addition, some conclusions were reached by examining cause and effect relationships in the data and several suggestions were made.

Results

Need Analysis

According to the data obtained from the first stage of the study, it was determined that SVI in 6th grade had some learning needs to be met in the field of science education. These needs are divided into four different groups: learning process, students, teaching materials and teacher needs.

Students who are interviewed consider science course as a useful and they are positive towards the course. However, the students suggest that this course targets vision sense mostly and that it is difficult to understand science subjects depending on their visual perception. According to observations, in science classes, students act in a memorizing manner and they try to memorize concepts rather than learn meaningfully. Direct instruction technique is used generally in lessons, textbooks are connected one to one and very few examples are given concerning daily life. The questions that students wonder about the subject during the course cannot be answered in a way to satisfy their curiosity or the answers given may sometimes be confusing and lead to misconception. It has been observed that students have many incomplete or incorrect knowledge as well as misconceptions about the 'cell' subject particularly basic parts of cell and structure/functions of organelles. For example, during observations and interviews, 'cell membrane feeds the cell', 'vacuole stores harmful substances such as coke and crisps', 'lysosome packets the substances by producing energy, renewed worn cells', 'endoplasmic reticulum makes intracellular digestion and transports necessary food into cell and keeps out those that are not needed' expressions were encountered. In addition, students used expressions such as 'cell wall in plant cells is green because plants carry chloroplasts', 'organelles are cell type things found in our organs', 'ours is the organ, but those in the cell are organelles'. In observations, it was observed that there was no cooperation between students and they could not gain the habit of listening to each other effectively. Students stated that they want to make experiments and activities by taking part in the experiments and activities themselves. Even if they do not see, they said that they want to examine cell under microscope, they can at least try to see it. Also they indicated that even if not available a microscope, they should be given a chance to study with enlarged and colored photocopies or tactile cell models.

Table 2 presents the responses of the need analysis group students to the questions prepared by taking into account acquirements in the curriculum and content of coursebook.

Table 2. States of Responding to Questions on 'Cell' Subject

Subject	Questions	$S_{A.1}$	$S_{A.2}$	$S_{A.3}$	$S_{A.4}$	$S_{A.5}$	$S_{A.6}$	%
Cell	1. What is Cell?	+	-	-	-	-	•	25
	2. How many groups are cells divided? What are the differences between them?	+	-	-	-	-	•	25
	3. What are the basic parts of the cell?	+	-	-	•	-	-	25
	3a. What are the tasks of the basic parts of the cell?	+	-	-	•	-	-	25
	4. What is organelle? Which organelles are found in the cell?	•	-	-	•	-	-	8
	4a. What are the functions of organelles in the cell?	•	-	-	•	-	-	8
	5. Are the cells visible by naked eye? What kind of tools should be used for see cells?	+	+	-	+	-	+	67
	6. What is the relationship between the development of the microscope/other technological tools and knowledge learned about the cell?	+	-	-	+	-	+	50
	7. How does a multicellular organism come from protozoa? (What structures are formed in the transition from protozoa to a multicellular organism?)	+	-	-	-	-	•	25
	%	89	11	0	44	0	39	
	Percentage of Average Achievement (%)							29

'Exactly correct response (+, 2 points), Partially correct response (•, 1 point), Incorrect response (-, 0 point)'

According to table 2, no student could reply to all questions exactly correctly. Besides, two students ($S_{A.3}$ and $S_{A.5}$) could not answer any questions correctly while the student $S_{A.1}$ showed the highest achievement with 89%. In addition, students were able to answer to fifth question at the highest percentage (67%) and to questions 4 and 4a at the lowest percentage (8%). According to the answers given by the needs analysis group, level of average achievement is 29% (Table 2).

The acquirements on 'cell' subject were classified according to the Bloom Taxonomy (Anderson & Krathwohl, 2014) and then the needs analysis group students' learning level of the acquirements were determined through observations and interviews. Finally, the differences between these two situations were revealed as the need. Table 3 shows levels of the three acquirements about 'cell' subject according to Bloom Taxonomy and students' states of reaching these acquirements.

Table 3. States of Reaching the Acquirements About 'Cell' Subject

Acquirements	Level								
	Knowledge Dimension	Cognitive Process Dimension	$S_{A.1}$	$S_{A.2}$	$S_{A.3}$	$S_{A.4}$	$S_{A.5}$	$S_{A.6}$	%
1. Compares the animal and plant cells in terms of basic parts and functions.	Factual	Understand	+	-	-	-	-	-	17
2. Discusses the opinions asserted regarding the structure of the cell in process from past to present by associating with technological developments.	Factual	Understand	+	-	-	+	-	+	50
3. Explains the relationship between cell-tissue-organ-system-organism.	Factual	Understand	+	-	-	-	-	-	17
%			100	0	0	33	0	33	

'Acquirement is reached (+), Acquirement is not reached or partially is reached (-)'

As can be seen from the table 3, while only one student ($S_{A.1}$) reached all achievements, two students ($S_{A.4}$ and $S_{A.6}$) could reach only second achievement. Also, three students ($S_{A.2}$, $S_{A.3}$ and $S_{A.5}$) could not reach any achievement on the subject. Furthermore, first and third achievements were reached by 17% and second achievement by 50% as well (Table 3).

As a result of interviews and observations, it was determined that SVI have difficulty in science courses. There are no specially designed materials that can be used in science teaching for SVI. The materials used in science teaching for sighted students are not responsive to the needs of SVI. The view of the $Teacher_2$ about this issue is given below.

> **$Teacher_2$:** *…There is much shortage of material in science course. Science courses should be mainly used puzzle. It's easy to teach something with using tactile puzzle. Students will assemble one by one the pieces of puzzle, then they will disassemble and assemble again. The student no longer don't forget subject. ...So, there must be concrete models. Also, they need to take the models home.*

In the focus group interview, students stated that they have a difficulty in preparing for course and repetition of subject. While blind students explained that they have difficulty in finding Braille resources, students with low vision expressed that they have difficulty in reading and understanding texts and drawings in textbook. Therefore, extern students ask their parents or siblings to read their textbooks, but boarder students explained that they ask for help from their friends for this. However, extern students said that their parents and siblings sometimes have works, they cannot take care of them and they have difficulty in finding someone to read textbook. Boarder students also stated that they do not understand anything due to weak reading skills of their friends. For this reason, the students indicated that they are trying to answer the questions in the exam with the information in their minds and as a result they received low grades.

> **$S_{I.5}$:** … ee My family reads text because I cannot read the text myself. But I don't understand much. I answer questions with the information in my mind, I also concoct what I cannot remember in the exam. That's why I always get bad grades.

As a result of interviews, the biggest demands of science teachers are that they want to have equipment and competence to meet educational needs of SVI with also other disabilities such as hearing, mentally or physically. Moreover, teachers state that they want to be able to prepare materials and activities appropriate for students' type and level of disability. Also, they expressed that in-service training should be given to them for learn braille alphabet. In this way, teachers think that they can read student writings and correct mistakes in writing.

Teacher1: *…The materials or activities that we can offer during the course are quite limited. This matter has an effect on the source of the problems.*

Teacher2: *… Education and training needs of schools and teachers should be determined. The teacher in this school must be well equipped. Required in-service training should be taken. …*At least, *I need to learn Braille in order to I can read what the student wrote.*

Designing and Implementation of Instruction

An instructional design was tried to be established in order to meet the learning needs identified during the needs analysis process and to ensure that basic science concepts about 'cell' subject can be learned effectively. For this purpose, the functional vision of each student were evaluated through using GFVAI and individual learning needs of students based on lack of their visual perception were determined. As a result of this evaluation, students' characteristics such as better sighed eye, focus on object/two objects, object tracking, near and far visual space, color vision, contrast sensitivity and reading/writing were determined and activities/teaching materials were selected/designed to meet needs of students and increase their conceptual learning levels. Following the determination of students' characteristics and needs through semi-structured interviews, observations and GFVAI, achievements about 'cell' subject were classified according to Bloom's taxonomy (Anderson & Krathwohl, 2014) and how these achievements would be addressed and it is planned that how them would be gained to the students. Within this framework, context to be included in instructional design was determined, learning environment was arranged, activities, teaching materials/methods to be used were determined. While determining activities and materials; different sources such as context in textbooks, student's workbooks, teacher's guides and various lecture notes were reviewed and activities suitable for individual needs of SVI were selected. In addition, it was not made any changes to activities/materials that allowable for SVI. However, necessary adaptations were made on activities/materials that blind/low vision students have difficulty to do. Also, knowledge sheets used in activities/materials were prepared. It has been considered that texts on knowledge sheets are in appropriate typefont and font size that can be read by low vision students (Arter, Mason, McCall, McLinden, & Stone, 1999; Çakmak, Karakoç, Şafak, & Kan, 2014). On the other hand, for blind students, braille printing was added on the texts for tactile sensing of these texts. Besides, simplified, vivid and contrasting colored drawings on knowledge sheets for low vision students are embossed in order to useful for blind students. Finally, teacher guide, which is planned to be used in the implementation phase, was prepared and learning environment was prepared for implementation. In addition, implementing teacher was informed about prepared activities, materials, knowledge sheets and teacher's guidebook usage. It was decided that these informing would be covered course in that week and be held in weekly periods. Then, implementation process was started. In implementation phase, instructional design was applied by teacher entering science course with the guidebook, while researcher made in-class observations in classroom as a non-participant observer.

The first activity called 'Road to Civilization' was designed to make students aware of historical development of microscope and discovery of the cell. This activity was also planned for students to understand the parts and function of microscope. After the students' preliminary knowledge was stimulated, low vision students watched the video documentary called 'Road to Civilization' while blind students listened to this video. During this process, video was stopped and descriptions were made where necessary (Figure 1).

Figure 1. Example of A Low Vision Student's Video Documentary Watching

After the video, parts of the light microscope were introduced to students and they were given detailed descriptions and were provided with microscopic examination. At this stage, students were given knowledge sheets on which embossed drawing of microscope and they were allowed to compare a real light microscope and its embossed drawing (Figure 2). Finally, students were asked evaluation questions about activity and the activity was summarized and ended.

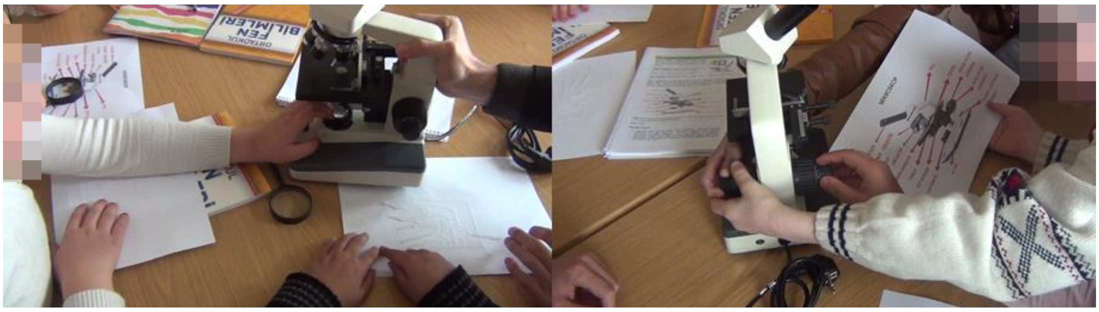

Figure 2. Example of Examining the Parts of Microscope by Blind and Low Vision Students

The aim of second activity called 'From Part to Whole' is to make students understand that living creatures consist of small structural units called cells. After a few questions were asked to students in order to stimulate their preliminary knowledge and increase their motivation, it was asked each student to create structures by lego pieces placed in front of them (Figure 3). Afterwards, students were asked evaluation questions and it was helped students with establish a similarity between lego pieces and cell. In this activity, through the lego pieces, it was made students concretely think about the idea that 'If lego pieces can combine to create any structure, the cells can also come together to create larger structures'.

Figure 3. Example of Creating Different Structures by Lego Pieces

Third activity named 'Smallest Structures Forming the Plants' was designed to enable students to understand that plants are composed of cells through observation of onion membrane. The students were first given a whole onion, then onion pieces, and students were asked to examine them by a magnifying glass. After, three different onion membrane sections that are dripped on a drop of water, lugol solution and methylene blue respectively were examined together with low vision students through a microscope. In the meantime, all processes were explained to blind students, and all students were given knowledge sheets on which a real microscopic image of onion membrane and basic parts of plant cell. The knowledge sheets given for blind students was prepared as embossed and this sheets were with tactile properties. Thus, the basic parts of cell were noticed easily by blind students (Figure 4).

Figure 4. The Implementation of Activity 3

After students were asked a few preparatory questions, fourth activity called 'Smallest Structures Forming the Animals' was started (Figure 5). The purpose of this activity is to recognize animal cell by microscopic examination intraoral epithelial cells and to learn similarities and differences between the plant and animal cells. Low vision students examined the epithelial cells by microscope in a similar way to the previous activity, while blind students observed knowledge sheets on which embossed real microscopic image of intraoral epithelial cells. Subsequently, all students observed knowledge sheets about basic parts of animal cell and compared these sheets with former sheets given to them in the previous activity about basic parts of plant cell.

Figure 5. The Implementation of Activity 4

The fifth activity, 'If Cells Begin to Talk', was designed to students comprehend basic parts of cell and compare them in terms of their functions. Firstly, students were given knowledge sheets about basic parts of cell and they were helped to read and understand these sheets. Secondly, each student was asked to select one of the basic parts of cell and to perform an animation with their friends (Figure 6). Finally, evaluation questions related to activity were answered, subject was summarized and activity was ended.

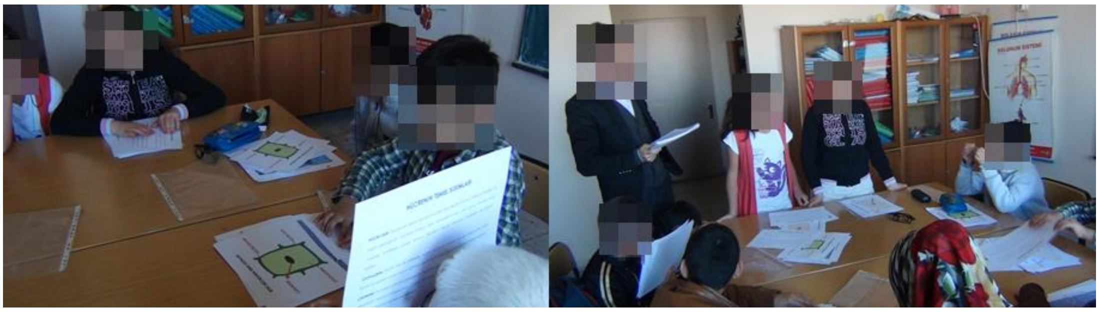

Figure 6. The Implementation of Activity 5

The purpose of the sixth activity called 'The Poet Organelles' is to enable students to understand the names and functions of organelles in plant and animal cells by poetic word and to comprehend similarities and differences of plant and animal cells in terms of the organelles they carry. First of all, students were distributed knowledge sheets about poem that contains knowledge about an organelle on its each quatrain and organelles drawing next to these quatrains. Meanwhile, 3D models of each organelle designed by the researcher were given to students respectively and detailed descriptions were given about these models. Students were also asked to examine these organelles in terms of structure, shape and size. Later, students were asked to select any organelles they wanted and to animate this organelle in classroom with other friends. At this stage, students were reminded that they could improvise (Figure 7).

Figure 7. Example of Examining 3D Organelle Models and Animating

After the animating, all students were given knowledge sheets on which colored embossed drawings about structure and organelles of plant and animal cells. At this time, necessary descriptions were given by taking care of blind students individualistically. Also, all students were given 3D models of plant and animal cell. Besides, blind students were helped to compare 3D models of plant and animal cells with knowledge sheets on which embossed drawings of these models (Figure 8). After examination of model and knowledge sheets, low vision students were provided with knowledge sheets on which comparison chart about structures and organelles of plant and animal cell. In view of the fact that this chart would be difficult to understand by blind students, knowledge in the chart were convert into plain text and printed in Braille. Then, evaluation questions related to the activity were answered together with students, subject was summarized and the activity was terminated.

Figure 8. Examination of Embossed Drawing About Plant and Animal Cells and Comparison with 3D Models

The seventh activity named 'Let's compare Plant and Animal Cells' was designed to teach students similar/different characteristics of plant and animal cells. Firstly, 'The Plant and Animal Cell 3D Magnetic Puzzle Set' designed by researcher were distributed to students and explanations about this set and they were given opportunity to examine parts of the set. This set consists of a plant and an animal cell (interior of cells are empty) embossed on a magnetic block and 3D models of nucleus and organelles (two for each) prepared for insert into these cells. Secondly, students were asked that embossed cell drawings belonged to which cell in terms of their shape and it was enabled them to realize that oval shape represented animal cell and angular shape represented plant cell. Then, students were asked to insert 3D models of nucleus and organelles into appropriate cells (Figure 9). In this process, students were helped to think about the structures and organelles common to both cells and only founded in the plant or animal cell. Finally, students were given knowledge sheets on which comparison chart about differences of plant and animal cells. Also, subject is reinforced by giving explanations about this chart. In view of the fact that this chart would be difficult to understand by blind students, expressions in chart were converted into plain text and then these texts printed in Braille. After, subject was summarized and activity was completed.

Figure 9. The Implementation of Activity 7

The aim of eighth activity called 'Journey from Cell to Organism' is to enable students to understand the concepts of cell-tissue-organ-system-organism and to relate between them. Students were given sufficient lego pieces to construct walls, rooms, apartments and buildings by thinking each of these pieces as bricks. At this stage, blind students were shown particular interest and all steps were explained in detail to them (Figure 10). Then, by helping of activity evaluation questions, students were provided with to make an analogy that structures constructed by themselves correspond to which structures in living organism. Lastly, concepts of cell, tissue, organ, system and organism were tried to comprehended by using torso (human body model).

Figure 10. The Implementation of Activity 8.

Evaluation of Instructional Design

In order to determine the usefulness of 'Cell' subject activities, to state how convenient the design is to the teaching and the student and to reveal functionality and practicality of these activities, evaluation was made by using SAOF. These evaluation results are presented in Table 4.

Table 4. Evaluation of Activities Related to the 'Cell' Subject

Evaluation Dimension	**Activity 1**	**Activity 2**	**Activity 3**	**Activity 4**	**Activity 5**	**Activity 6**	**Activity 7**	**Activity 8**
1. Compatibility to Instruction								
1.1. Do questions asked at the beginning of activity examine preliminary information?	+	+	+	+	+	+	+	+
1.2. Can pre-activity preparation questions raise awareness of activity?	+	+	+	+	+	+	+	+
1.3. Is enough time given for the introduction of activity and materials to be used?	+	+	+	+	•	-	•	+
1.4. Is activity consistent with the purpose of subject?	+	+	+	+	+	+	+	+
2. Compatibility to students								
2.1. Does activity allow the use of different senses?	+	+	+	+	+	+	+	+
2.2. Has activity been adapted from daily life events?	+	+	X	X	+	X	X	+
2.3. Can activity help to relate to previous learnings?	+	+	+	+	+	+	+	+
2.4. Does activity enable student to participate in lesson physically and mentally?	+	+	+	+	+	+	+	+
2.5. Does activity attract students?	+	+	+	+	+	+	+	+
2.6. Does activity meet the cognitive characteristics of target group?	+	+	+	+	+	•	+	+
3. Functionality								
3.1. Is the activity capable of achieving the relevant objectives?	•	+	+	+	+	•	+	•
3.2. Are the materials used in activity suitable for reuse?	+	+	•	•	+	+	+	+
3.3. Is the activity capable of allowing student to work independently?	+	+	•	•	+	+	+	+

Table 4. Continued

Evaluation Dimension	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8
3. Functionality								
3.4. Does the activity have ability to be adapted to individual differences?	+	+	+	+	+	+	+	+
4. Practicality								
4.1. Is the time planned for the activity sufficient?	+	+	+	+	+	-	+	+
4.2. Are the materials used in the activity cost-effective?	+	+	+	+	+	•	•	+
4.3. Are the materials used in the activity easily accessible?	+	+	+	+	+	•	•	+
4.4. Are the materials used in the activity easy to use?	+	+	+	+	+	+	+	+
4.5. Does the activity prioritize the safety of the student?	+	+	+	+	+	+	+	+

'Suitable (+), Partially suitable (•), Not suitable (-), Not applicable (x)'

According to Table 4; with regards to the efficiency of time given for introduce of activity and materials, fifth and seventh activities are partially suitable and sixth activity is not suitable. Students had difficulty in examine materials given them in these activities, reading and understanding knowledge sheets and animating and they needed more time than planned. When examining the given 3D materials, more attention should be paid to these students and detailed descriptions should be made. In addition, sixth activity was partly suitable in terms of accord with cognitive characteristics of target group and ensuring achievement of relevant objectives. Because students have poor reading comprehension skills and they needed more time and practice to read and understand texts given to them and make them animate in front of their peers.

According to functionality dimension; first and eighth activities were partly sufficient to achieve relevant objectives because of the teacher inexperience about utilizing guidebook, asking questions, getting answers, helping students find correct answer, and classroom management. (Table 4). Besides, in third and fourth activities, low vision students need more support in microscopic examination, while blind students could not benefit from the microscope image and blind students were able to observe embossed microscopic images on knowledge sheets. For this reason, third and fourth activities were considered to be partially suitable in terms of the criterion of allowing students to work independently.

In practicality dimension; sixth activity was not suitable for adequacy of planned time for the activity, and more time was needed due to the students' lack of reading and comprehension skills and their inability to do animation. In addition, materials used in sixth and seventh activities were also found to be partially sufficient in terms of criteria such as cost-effectiveness and easy to accessible (Table 4). In these activities, cell nucleus and organelle models are designed using a 3D printer. Although printing from a 3D printer is low cost, but 3D printer is an expensive tool. If this printer is not available, it is difficult for such materials to be affordable and easily available.

At the end of the implementation, regarding cell subject, questions that prepared by taking into consideration acquirements in curriculum and content of coursebook, and that previously had asked to the group of needs analysis (Table 2) also were directed to group of implementation. Thus, it was revealed that how concepts related to subject were learned in group of implementation. The comparison of answers to questions asked to both group of needs analysis and implementation will give an idea of the usefulness of design because students are not the same, but they are similar in terms of their level of vision, individual needs and readiness. The needs analysis and implementation group students' answers to questions about 'Cell' subject were compared below (Table 5).

Table 5. Comparison of Responding Status of the Questions on 'Cell' Subject

Questions	Group of Needs Analysis						Percentage of Achievement (%)	Group of Implementation									Percentage of Achievement (%)
	S_1	S_2	S_3	S_4	S_5	S_6		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	
1	+	-	-	-	-	•	25	+	+	+	+	+	+	+	+	+	100
2	+	-	-	-	-	•	25	+	•	+	+	+	-	+	+	•	78
3	+	-	-	•	-	-	25	+	•	+	+	+	+	+	+	+	94
3a	+	-	-	•	-	-	25	•	•	+	+	+	•	+	+	•	78
4	•	-	-	•	-	-	8	+	-	•	•	•	•	+	+	•	61
4a	•	-	-	•	-	-	8	-	-	-	•	•	-	+	+	•	39
5	+	+	-	+	-	+	67	+	+	+	+	+	•	+	+	+	94
6	+	-	-	+	-	+	50	+	+	+	+	+	+	+	+	+	100
7	+	-	-	-	-	•	25	+	-	+	-	•	•	+	+	+	67
%	89	11	0	44	0	39		83	50	83	78	83	56	100	100	78	
Percentage of Average Achievement (%)							29	Percentage of Average Achievement (%)									79

'Exactly correct response (+, 2 points), Partially correct response (•, 1 point), Incorrect response (-, 0 point)'

It can be seen from Table 5 that group of needs analysis showed an average success rate of 29% in the questions directed to them and that implementation group was able to give correct answer to these questions with a rate of 79%. Considering response rates of the questions, although increase in all the questions was observed, highest achievement growth was first question with a rate of 75%, and least achievement growth was question 4a (31%). According to students, it is difficult to pronounce the names of organelles and keep them in mind, and students may confuse the functions of organelles because their names are very similar. For this reason, it can be argued that answer rate of question 4a is lower than the other questions. In order to solve this problem, it is thought that it may be useful for students to do more practice and to participate in activities related to subject frequently.

From table 5 can be shown that there were no students who could answer all questions correctly in group of needs analysis, whereas in implementation group, students (S_7 and S_8) were able to answer all the questions accurately. Also, while two students in needs analysis group (S_3 and S_5) could not answer any questions correctly, there were no students in implementation group who could not answer any questions correctly. According to percentages of responding to questions, all students in group of needs analysis showed a success rate of 44% or less except for one student (S_1). On the other hand, in group of implementation, there is no student who has less than 50% success.

The needs analysis and implementation group students' level of reaching to three acquirements in curriculum regarding 'cell' subject is compared in the Table 6. As shown in table 6, in group of needs analysis, the level of reaching to first and third acquirements is 17% while to second acquirement is 50%. However, in implementation group, this rate is 56% for first and third acquirements and 100% for second acquirement. In this case, the rate of increase in reaching to first and third acquirements is 39% and the rate of increase in reaching to the second acquirement is 50%. For level of reaching to achievements, if it is considered that low success is rate of 0-30%, that moderate success is 30-70% and that high success is rate of 70% and above, moderate success (56%) was obtained in reaching to first and third acquirements, and high success (100%) was achieved in reaching to second acquirement (Table 6).

Table 6. Comparison of Reaching Levels the Acquirements About 'Cell' Subject

	Students	Acquirement 1	Acquirement 2	Acquirement 3	Percentage of Achievement (%)	Percentage of Average Achievement (%)
Group of Needs Analysis	$S_{A.1}$	+	+	+	100	28
	$S_{A.2}$	-	-	-	0	
	$S_{A.3}$	-	-	-	0	
	$S_{A.4}$	-	+	-	33	
	$S_{A.5}$	-	-	-	0	
	$S_{A.6}$	-	+	-	33	
Percentage of Achievement (%)		17	50	17		
Group of Implementation	$S_{I.1}$	-	+	+	67	70
	$S_{I.2}$	-	+	-	33	
	$S_{I.3}$	+	+	+	100	
	$S_{I.4}$	+	+	-	67	
	$S_{I.5}$	+	+	-	67	
	$S_{I.6}$	-	+	-	33	
	$S_{I.7}$	+	+	+	100	
	$S_{I.8}$	+	+	+	100	
	$S_{I.9}$	-	+	+	67	
Percentage of Achievement (%)		56	100	56		

'Acquirement is reached (+), Acquirement is not reached or partially is reached (-)'

According to Table 6, in group of needs analysis, the students $S_{A.2}$, $S_{A.3}$ and $S_{A.5}$ were not able to reach any acquirement, while the student $S_{A.1}$ reached all the achievements. On the other hand, in group of implementation, three students ($S_{I.3}$, $S_{I.7}$ and $S_{I.8}$) were able to reach all acquirements, while there was no student who cannot reach any acquirement. Also, in terms of reaching to acquirements, the average achievement in group of needs analysis was 28%, while in implementation group was 70%.

Discussion and Conclusion

As a result of interviews, SVI stated that they consider science as a course that contains information from daily life and enables them to get to know themselves and their environment. However, the students expressed that they had difficulty in understanding this course since it is processed by using methods that require using the sense of sight. Many studies have also revealed that SVI face with access barriers to science course and they need auditory and tactile contents to eliminate these barriers (Bell & Silverman, 2019; Fraser & Maguvhe, 2008; Kalaycı, 2001; Kumar et al., 2001; Okcu et al., 2016; Sözbilir et al., 2015). In class observations, it was seen that information was transferred only verbally, materials were rarely used, activities and experiments were not done too much, students were only listening information presented to them and were trying to memorize, and interaction and cooperation between them were weak. Besides, it was observed that feedback and reinforcements given to students were not at a sufficient frequency and level, and that questions asked by teacher did not increase students' interests and motivations towards course. Akakandelwa and Munsanje (2011) determined that appropriate and sufficient teaching materials were not provided for SVI, and therefore students had serious performance degradation in course and that various teaching materials were needed in science/mathematics courses suitable for their individual needs. If SVI are involved in a constructivist teaching process that includes activities and materials that allow them to use their various senses; their interest and motivation in course increases, it is easier for them to reach scientific knowledge and be successful in concept learning (Sözbilir & Okcu, 2019; Sunal & Sunal, 2003). Research evidences suggest that SVI succeed by using three-dimensional models in writing and balancing chemical reactions, unit conversions and concentrations calculation, drawing Lewis dot structures, understand structural representations of molecules and determination of organic functional groups (Boyd Kimball, 2012). Furthermore, they were able to perform a simple titration experiment with the help of four different smell indicators (Flair & Setzer, 1990).

According to results of observations and semi-structured interviews with students, many incomplete or incorrect information as well as misconceptions about 'cell' subject were found. Although any studies that reveal misconceptions of SVI about 'cell' subject have not been encountered in literature, it is known that sighted students have difficulty in understanding 'cell' and 'cell division' subjects and have developed various misconceptions as well (Akyürek & Afacan, 2013; Dreyfus & Jungwirth, 1988; Flores et al., 2003; Yılmaz et al., 1998).

In this study, materials were used so as to provide SVI's visual knowledge as well as tactile such as various models, lego pieces and information sheets in implementation phases to improve their conceptual learning. Students also gained experience through activities that they actively participate in, perform drama/animation and make observations using different senses. It is asserted that the students' academic achievements and their interest and motivation to science may be high and learned knowledge may be more permanent and useful, If some adaptations are made according to the needs of SVI for smoothly access to the curriculum, various activities/materials suitable for their disability levels are used and they are helped to follow scientific process skills such as observation, measurement, classification, recording/using data, hypothesizing/testing, constituting models, changing/checking variables, and experimentation (Kızılaslan & Zorluoğlu, 2019; Koenig & Holbrook, 2000; Lowenfeld, 1974).

It can be said that first activity which students are expected to have knowledge about the historical development of microscope and discovery of cell and to understand parts/function of microscope is successful in achieving related instructional objectives. However, due to the insufficient professional experience of teacher who implemented the instruction, some of the skills planned to be reached by students have experienced problems. For instance, some questions in teacher's guidebook, which were planned to be asked to students, were not asked by teacher as planned. Besides, in some questions, teacher tried to get answers from students without creating a discussion environment and not using brainstorming technique. Because of these reasons, some skills related to scientific process skills, life skills and science-technology-society-environment (STSE) learning domain have not been sufficiently gained by students.

In second and eighth activities that were performed for the purpose of understanding the concepts of cell-tissue-organ-system-organism and relating between them, students created various structures using the lego pieces, in this way, they had fun and learned the biological organization that growing from cell to organism. On the other hand, since the students could not be directed as planned during the activity and they could not comprehend the purpose of the activity, there was occasional confusion in classroom and the activity could not be maintained as desired. This situation was distracted the teacher and could not fully adhere to instructions in guidebook. For example, based on the hierarchy growing from cell to organism, the importance of national unity was not emphasized, various science fields and scientists working in these fields were not mention, also artificial organ subject were not adequately addressed. Therefore, students could not show expected success in learning domains such as life skills (analytical thinking), affective (to appreciate contribution of science, responsibility of individual and social) and STSE (the nature of science, relationship between science and technology, the social contribution of science, science and career awareness). Consequently, in activities where materials that attract attention of students are used, it is necessary to be careful not to see the activity as a game by students and not to deviate from its aim. Also purpose of activity should be clearly explained to students. Students should focus on issues such as what they should do in activity, what their purpose is, and what they intend to learn at the end of the activity (Kumar et al., 2001).

In the third and fourth activities, the students showed great interest in examine samples of plant/animal cells under microscope, students with low vision easily gained the skills expected of them in these activities. However, because microscopic examination is not a task that blind students can perform independently, they were helped during activities more than planned. They were also distributed braille printing knowledge sheets on which there are true microscopic images of the cells. Thus, students were able to observe the knowledge sheets at any time and were able to recognize main similarities/differences between plant and animal cells through their knowledge sheets. In fact, in various studies, it was recommended to use knowledge sheets containing tactile data in science teaching to SVI (Cooperman, 1980; Harshman et al., 2013). In addition, functional visual levels and the presence of additional disabilities should be taken into consideration in order that students can access the curriculum through printed sources, and depending on the nature of the tasks requested from them, it should be make various adaptations that students need such as Braille/large print, tactile relief/models, screen reader/magnification and use of optical devices (Bell & Silverman, 2019; Sözbilir & Okcu, 2019; Willings, 2017).

Fifth and sixth activities carried out to understand the names/functions of the basic sections and organelles of plant and animal cells and to compare similarities/differences of these cell in terms of organelles they carry, have been generally successful and contributed to development of planned skills. However, due to students' weak reading and comprehension skills, they needed more time to read and understand texts and quatrains in knowledge sheets was given to them. This situation caused the activities to take more time than planned. Moreover, the performances of students were not at expected level due to their inexperience of performing drama/animation and their low level of reading comprehension skills. The students tried to memorize texts and quatrains in knowledge sheets instead of understanding and animating them. They only repeated them in front of other students, but they were not very successful in this too. For this reason, if more activities related to improve reading comprehension skills are done and perform drama/animation much more, students' learning tendencies by memorizing can be reduced and their skills such as creativity, entrepreneurship, communication and teamwork can be improved through drama/animation.

In seventh activity made in order to understand the similarities/differences of plant and animal cells, 'The 3D magnetic puzzle set of plant and animal cell' designed by researcher attracted the attention of students and they competed with each other in order to participate in the activity and use this set. However, some students had more difficulty than others in recognizing the 3D organelles and fitting them into related cells. Therefore, it was made more detailed descriptions and was expressed more clearly purpose of activity to these students. On the other hand, the source of the problem can be said that to be related to previous activity. In activity 6, because 3D organelle models could not be introduced to students sufficiently by teacher, incomplete learning was realized and this case was reflected in seventh activity. For this reason, to make it easier for students to determine which model belongs to which organelles, teacher told students who can use knowledge sheets containing texts and organelles drawings that given to them in activity 6 while fitting 3D organelle models in cells. Meanwhile, 3D models were described in detail to blind students by teacher. The blind students were confused mitochondria with chloroplast and endoplasmic reticulum with golgi apparatus. However, if more detailed descriptions are made, it is thought that this problem can be solved.

Suggestions

In order to meet needs identified after observations and interviews carried out in analysis phase, instructional model was designed and developed. The factors that may affect the usefulness of activities, tools and materials included in this model were determined and these factors were considered in implementation phase. In this respect, it should be ensured that activities in instructional design are accordant with students' cognitive characteristics and needs. Also, it should be noted that these activities should be related to prior learning and that materials used in activities should allow use of different senses. In the study, it was seen that knowledge sheets used for SVI to reach written sources on subject were very useful for learning. Students were able to read and examine knowledge sheets given to them both inside/outside of course and were able to often repeat subject. In preparing hard copy for SVI, different adaptations such as font size, vibrant/contrasting colored figures/drawings (for students with low vision) or Braille printing and embossed/tactile figures/drawings (for blind students) should be made according to visual level of students. Because it is difficult for blind students to make sense of tables, tables on hard copy should be converted into prose and printed with Braille. Besides, drawings and schemes should be simplified as much as possible, embossed and tactile properties should be gained. It is seen that this is not useful due to difficulty of reading in case of visible writing together with Braille printing in prepared knowledge sheets for students with low vision. For this reason, it is considered that it would be more useful to write only visible writing on knowledge sheets to be prepared for student with low vision. However, for blind students, it should be paid attention that both Braille printing and visible writing should be written on knowledge sheets prepared in order that teachers and parents who do not know Braille can understand text and help students when required.

In this study, it was seen that designed for comprehending abstract concepts and used 3D models were found to be very useful, and it was concluded that students developed their conceptual learning and made it easier to reach related academic achievements. But 3D material design is a difficult and costly process. For this reason, use of 3D printers in education for SVI should be expanded and schools should be provided with financial resources and necessary training should be given to users. In addition, among materials designed for blind students, embossing drawings on a two-dimensional plane should be use firstly. Later, 3D models representing these objects should be used and finally, real of these objects should be used if there is no obstacle or danger in their use. Thus, blind students will be able to study with more complex and detail materials starting from simplest and most understandable materials and these students will be able to understand concepts more easily in their minds.

Based on the problems encountered in a few activities in implementation process, the goals and objectives of activity should be clearly stated before students are included in any activity, and during the activity, students should be guided with frequent descriptions and explanations about how to use the materials given to them and what results they should achieve. Otherwise, students can regard activity as a game and deviate from the purpose of activity and there may be confusion in classroom. Within study, it was seen that drama/animation activities made lesson funnier and contributed to learning. However, some students did not show expected success because of some students' low reading comprehension skills and lack of experience in making drama/animation. Thus, in teaching for SVI, it should be ensured that students gain various skills and experiences by giving priority to making activities that contribute to development of reading comprehension skills and containing tasks that students are inexperienced.

Finally, because there are very few and small scale studies related to science teaching (particularly on biology subjects) for SVI in literature, more studies should be conducted in this field and these studies should particularly focus on obtaining tangible data for implementation. There is also a need for studies aiming to reveal misconceptions of SVI in various science subjects. In addition, it is thought that it would be beneficial to focus on studies about design of 3D materials that contribute to embody of concepts.

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