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A Product of the Instructional Design Process Developed According to the Seels and Glasgow Model: Interactive Hologram-Supported Material Set

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A Product of the Instructional Design Process Developed According to the Seels and Glasgow Model: Interactive Hologram-Supported Material Set

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Abstract

This study aims to design an educational process for teaching scientific concepts during the preschool period based on the instructional design model of Seels and Glasgow and to evaluate its effectiveness. For this purpose, a material set incorporating a teacher's manual and interactive holographic materials was developed. The teacher's manual developed has an inquiry-based approach according to which scientific concepts are structured in line with scientific information. Expert opinions were obtained regarding the developed material set. It was determined that the material set developed in line with expert opinions may be supportive in teaching scientific concepts in the preschool period. Moreover, it was found that the developed material set helped the concretization of abstract concepts that are difficult to observe and that require a process and assisted the children in constructing scientific information in their minds by way of generating realistic three-dimensional images. It is anticipated that, with the interactive holographic material set developed during the research, the lack of materials and scientific information in the preschool teaching process of scientific concepts may be prevented.

Keywords: Holographic technology, Seels and Glasgow model, Preschool, Scientific process skills

Introduction

Innate senses of curiosity and discovery lead the preschool children to make sense of their environment. In this process of making sense, children act as scientists to reach information (Casteel, 2017). Beginning the science education in this period, during which a child is full of curiosity, favourably affects the sense of curiosity as well as motivation for science (Eshach and Fried, 2005). Science education given during this period has an important role in rendering children aware of the concepts and events of the world (Campbell and Jobling, 2012). In addition, science education provides the opportunity for the children to inquire about the world, solve problems, and develop their problem-solving skills and thinking abilities (Samarapungavan, Patrick and Mantzicopoulos, 2008). Therefore, the education given during the preschool period is critical for a child's development.

The basis of science education is to make sense of real-life events and circumstances; hence, science education is an inquiry-based discipline (Rönnebeck, Bernholt and Ropohl, 2016; Mariegaard, Seidelin and Bruun, 2022). In an inquiry-based approach, children ask questions and seek answers to the situations they wonder about. They even try to explain the reality and causes of the situations they come across in their surroundings and make inferences regarding these situations. Moreover, it is known that the activities of inquiry-based learning contribute to the development of scientific process skills in students (Stout, 2001; Sullivan, 2008; Şimşek and Kabapınar, 2010; Wu and Hsieh, 2006; Wu and Krajcik, 2006). Structuring concepts in line with scientific information through inquiry-based science education may develop children's skills of observation, comparison, categorization, communication, measurement, anticipation, and inference (Jackman, 2011). In this way, children may make sense of the causes-results of concepts or events more easily (Trundle, Atwood, Christopher and., Saçkes, 2010). During the preschool period, children go through a fast-paced concept generation process. In order to prevent any mislearning and misconceptions (alternative concept), technology must be used effectively (Yilmaz and Siğirtmaç, 2020).

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Concepts are learned through the activities or experiences of the child (Fleer, 2009; Tu and Hsiao, 2008). In this respect, it is important to make room for real-world-based materials in educational environments to allow children to make sense of items such as scientific phenomena and concepts correctly in their minds. Enriched educational environments generated with the support of various technological materials may help children concretize concepts and thus contribute to permanent learning (Altun, 2018). However, it is a known fact that children's concentration processes differ from those of adults and that the former get bored easily (Cameron, 2005). On the other hand, children's capabilities of differentiating between imagination and reality, as well as between the living and the lifeless have also not been developed yet in the preschool period. For the sake of generating appropriate learning environments, such characteristics of children must be taken into account; it is possible to integrate technological materials that fit the children's level of development into the preschool curriculum.

It was determined that the use of technology in the preschool period furnished children with the skills preparing them for primary school and enhances their permanent learning (Brooker and Siraj-Blatchford, 2002; Roopa, Prabha and Senthil, 2021). develops their memory skills (Haugland, 1999), gives them the opportunity to learn through practise and experience (Kara and Çağıltay, 2017), and increases their motivation (An, Morgenlander and Seplocha, 2014; Yılmaz, 2016). It is known that, for the children of the preschool period, during which abstract concepts are hard to grasp, the use of technology, considering their developmental characteristics, helps children visualise difficult or abstract concepts (Futschek and Moschitz, 2010; Klein, Nir-Gal and Darom, 2000). Moreover, it was observed that technology develops children's skills in areas such as creativity, critical thinking, and problem-solving (Blackwell, Lauricella, and Wartella, 2014; Siraj and Siraj, 2001), lends them the opportunity to work in cooperation and enhances their communication skills (Shifflet, Toledo, and Mattoon, 2012), allows them to be active in the learning process and favourably affects the learning process (Karadeniz, Samur and Özden, 2014), and develops their listening skills (Yilmaz, Küçük and Göktaş, 2017). It is stated that technology supports children's learning and helps them share their experiences. In addition, technology is important for the improvement of children's social, emotional, physical, and cognitive development (Clements and Sarama, 2003; Plowman and McPake, 2013; Plowman and Stephen, 2003; Yelland, 2011) as well as enriching their educational processes (Blackwell et al., 2014; NAEYC, 2012). Hence, considering the potential benefits of using technology correctly, it is indispensable to integrate technology into the preschool curriculum (NAEYC, 2012; Plowman and Stephen, 2007; Spektor-Levy, Plutov, Israeli and Perry, 2017).

With hologram technology, one of the three-dimensional technologies (like augmented reality, virtual reality, etc.), realistic images started to be used as an alternative to customary two-dimensional images (Mnaathr and Basha, 2013). When compared to two-dimensional technologies, three-dimensional technologies provide students the opportunity to learn through practise and experience by allowing them to examine the designed objects from different angles (Wu, Lee, Chang, and Liang, 2013). In this regard, when using three-dimensional technologies, students actively take part in the process, which enables permanent learning (Chen, Chi, Hung, and Kang, 2011; Dunleavy, Dede, Mitchell, 2009; Wojciechowski and Cellary, 2013). Moreover, these technologies attract children's attention and render the learning process more exciting for them (Oh and Woo, 2008; Wojciechowski and Cellary, 2013; Zhou, Cheok, and Pan, 2004). Accordingly, three-dimensional hologram technology would contribute to concretizing abstract concepts, easy comprehension of subjects that are difficult to grasp, the presentation in a realistic manner of objects and events that cannot be observed or that require a process of observation, and children's meaningful learning (Barkhaya and Halim, 2017; Eschenbrenner, Nah, and Siau, 2008; Ghuloum, 2010). Thus, it becomes possible for the children to understand concepts correctly and to generate schemas accordingly in their minds by giving them the sense that the objects that are indeed not present at that specific location, are there (Odabaşı, 2015). Moreover, it is mentioned that the use of three-dimensional hologram technology for educational purposes enhances the quality of educational processes (Ghuloum, 2010). Several reasons have been put forward in favour of using this technology in the area of education. To name a few: its ability to contribute to the development of children's cognitive skills by increasing attention, participation, and interaction (Barkhaya and Halim, 2017), to provide the learners with convincing images (Kalansooriya, Marasinghe and Bandara, 2015), to develop spatial thinking skills and depth perception (Okulu and Ünver, 2016). In this respect, using this technology in the instruction of scientific concepts that are difficult to grasp and that require a process would favourably affect learning. Moreover, as it is known that the education given during the preschool period is critical in terms of children's development, providing education in this period on a sound basis (Hadzigeorgiou, 2001), is significant for the generation of the right schemas in children's minds and for the prevention of conceptual confusion.

When the relevant literature about the use of three-dimensional hologram technology in education was examined, it was observed that this technology is used more frequently in medical science and engineering (Golden, 2017; Hackett, 2013; Hackett, 2018; Freeman, 2010; Kalansooriya et al., 2015; Musion, 2014; Khan et al., 2013, Romero et al., 2015; Sudeep, 2013; Vanden Bosch et al., 2005), while no studies were encountered in the area of preschool science education. However, in their study with science teacher candidates, Okulu and Ünver (2016) mentioned that the education given with this technology would favourably affect spatial thinking ability and depth perception. Mnaathr and Basha (2013) state that hologram technologies may be used for easing comprehension of scientific topics and teaching concepts in science education. Olson (2013), on the other hand, especially proposes the use of 3D hologram technology in the area of science. As regards preschool education, Monnin (2010) emphasises that 3D technology excites children and attracts their attention, and Barkhaya and Halim (2017) stress that this technology constitutes interactive material that attracts the attention of children in the learning process and contributes to the development of their cognitive skills in the best way. In this context, this research aimed to design a learning process for teaching scientific concepts during the preschool period and to assess its impact. It was decided that, with regard to the interactive holographic material set (teacher's manual and interactive holographic material), the Seels and Glasgow instructional design model is appropriate for the cyclical improvement of the design, development, implementation, assessment, and commissioning processes of the material. This model was selected because it is a product-oriented model that is based on systemic work on instructional problems and learning conditions. The Seels and Glasgow model is designed for product and course developers, with the expectation that the results will be disseminated for others to use. This model, which considers design and development in the context of project management, focuses on the fact that the steps in the instructional design phase are interdependent and simultaneous and should be handled in an iterative cycle (Gustafson and Branch, 2002).

Designing the Learning Process

In this study, Design and Development Research was used as the research model. Design and Development Research systematically addresses the design, development, and evaluation of instructional models, curricula, instructional tools, instructional processes, and instructional products (Richey and Klein, 2007). Design and Development Research is an important research method in the field of instructional technologies as it helps researchers in the process of developing instructional products (Çağıltay and Göktaş, 2013). In this study, which is a Design and Development Research, Seels and Glasgow instructional design model was used as the basis for the design and implementation of the learning process. Seels and Glasgow instructional design model consists of different phases and sub-titles under these phases. Seels and Glasgow instructional design model was defined as the systematic analysis of learning conditions and learning problems. The model was established on a linear structure and has ADDIE's project management process covering analysis, design, development, implementation, and assessment phases (Seels and Glasgow, 1998). The model has problem analysis in the problem phase; task analysis and instructional analysis; determination of objectives and benchmarks; instructional strategies and delivery systems in the design phase; material development and formative evaluation in the development phase; implementation , maintenance, and summative evaluation in the implementation-evaluation phase. Four phases of this model are presented in Figure 1 by separating them from each other by different colours.

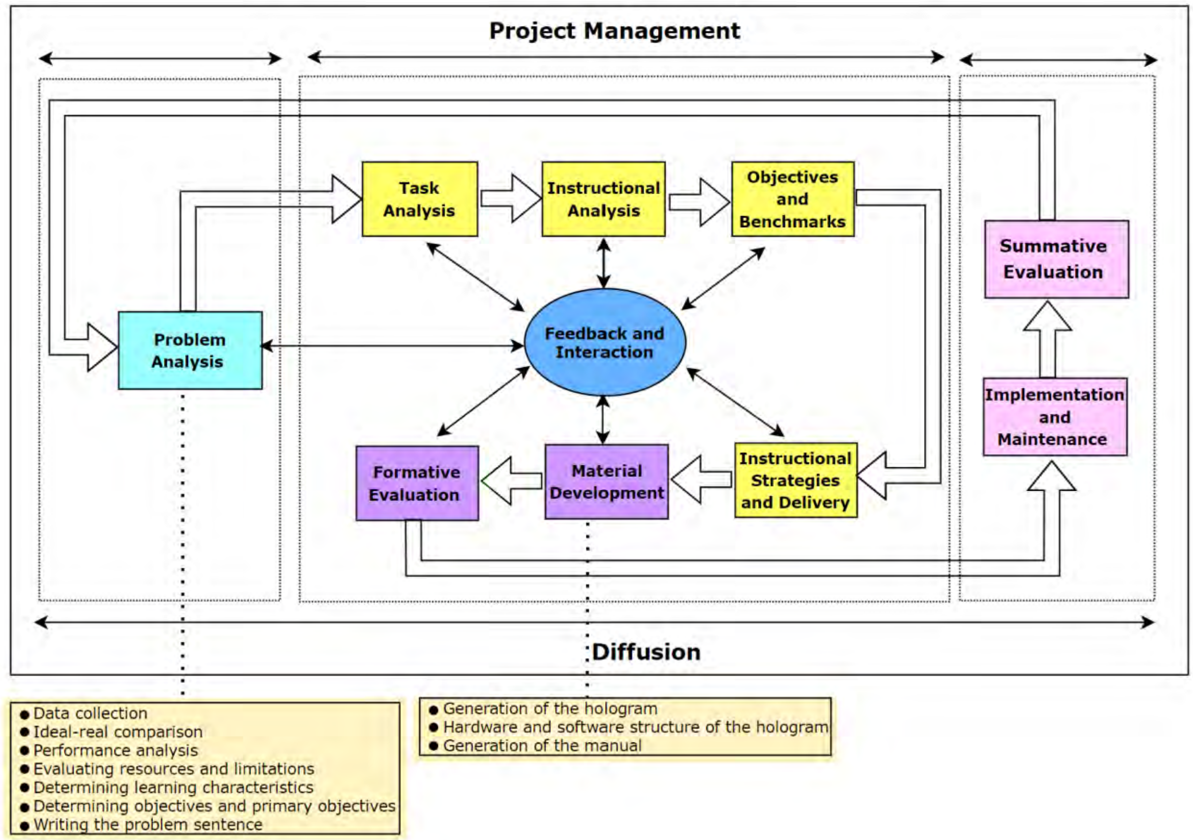


Figure 1. An adaptation of the Seels and Glasgow instructional design model to this study

Seels and Glasgow is a compound model structured on the basis of a core and an interactive model (Şimşek, 2009). It addresses instructional design as a process of the core model while focusing on the correction of the disrupted aspects of this process with its interactive model (Figure 1). In the Seels and Glasgow model, in order to present more stable designs to learners and to make more efficient production, the process is continuously reviewed before its competition (Keleş, Erümit, Özkale and Aksoy, 2016). Information is presented below about how the instructional design process is carried out for 3D interactive holographic material set according to the Seels and Glasgow model. Each lower step of the model is provided by detailing what kind of systematic transactions about instructional design are performed in that particular step.

Problem Analysis Phase of the Seels and Glasgow Model

The first phase of the Seels and Glasgow model, namely the problem analysis phase, incorporates "collection of data, ideal-real comparison, performance analysis, evaluation of resources and limitations, determination of learning characteristics, determination of objectives and primary objectives, and writing a problem sentence" (Seels and Glasgow, 1998, p. 196).

a) In the data collection process, several tools are made use of, such as surveys, observation and interviews, in order to gather information about the content of the research envisaged to be done and regarding the student, teacher, and learning environment. The teacher plans, implements, and evaluates the learning process; in other words, the teacher is the one who shapes the learning process and thus has a direct impact on the learning processes of children. Accordingly, within the scope of the research, 32 preschool teachers who serve across the country were determined on a voluntary basis, and through an electronic survey composed of open-ended questions, their opinions were obtained on which scientific concepts are difficult to be taught, why such difficulty is faced, and the usability of hologram technology in the instruction of the concepts that are difficult to grasp.

b) In the ideal-real comparison process, a potentially accessible situation is determined by considering the desired and current conditions. When the scientific concepts, about which teachers consider themselves to have insufficient knowledge, were analysed, as they were high in numbers and consisted of different areas, the determined concepts were narrowed down. Therefore, among the concepts of the preschool curriculum, the concepts in the area of "Earth and Space Sciences" were focused. These concepts were determined to be 'Rain', 'Snow', 'Hail', 'Fog', 'Cloud', 'Lightning', 'Rainbow', 'Night', 'Day', 'Earth', 'Sun', 'Moon'; 'Spring', 'Summer', 'Fall' and 'Winter'. Moreover, it was determined in line with the opinions obtained from Computer Education and Instructional Technology (CEIT), science, and preschool education experts that the interactive holographic material set must be applied to children at the age of 60 months and older. Age groups were narrowed down with the consideration that other age groups in the preschool period may lose their sense of reality in this process.

c) In the process of performance analysis, conditions such as the knowledge and skills of the teacher as well as the student's success and motivation are analysed. Except for the 32 preschool teachers serving throughout the country, some preschool teachers were selected randomly, and primary interviews and observations were made one-on-one. As a result, it was observed that teachers lacked sufficient knowledge about scientific concepts. Furthermore, it was determined that in teaching the relevant concepts, they either do not make room for a great deal of scientific information or evade explaining these concepts.

Enough silence is ensured in the classroom, and students' seating arrangements have been appropriately made under the influence of the teacher. These situations favourably affect student performance. It is considered that children's interest may be increased by providing concrete examples. This interest would also favourably affect the performance in the class. Moreover, as a result of the interviews with the preschool teachers, the operational course of the lesson was planned by observing the differences in learning styles and speeds of children.

d) In the process of evaluating resources and limitations, current resources and training materials are examined, and limitations are determined. In this respect, it was determined in the research that teachers treat the concepts by using videos, drama techniques, and verbal explanation and that they experience a lack of materials in the teaching process. In addition, it was found that teachers lack scientific knowledge in relation to scientific concepts. It was considered that this situation may be solved by making use of concrete materials convenient to children's developmental characteristics and prepared in the light of scientific knowledge.

e) In the process of determining learning characteristics, the fact that the content is composed of which of the cognitive, affective, and kinesthetic behaviours, is focused is important. As the focus here is the teaching of preschool scientific terms by using holographic material, children's cognitive behaviours were taken as a basis.

f) In the process of determining objectives and primary objectives, the main and primary objectives of the research are determined. Accordingly, in order to reach the objectives determined within the framework of the research, our focus has been on the development of a material set that allows for teaching the concepts regarding the "Earth and Space Sciences" via an interactive holographic material set and the evaluation of the effects of this material set on the learning process.

g) In the process of writing the problem sentence, the situation that emerged in the problem analysis step is analyzed, and the problem sentence is generated. Accordingly, the problem sentence of this research is the design of an instructional process for teaching scientific concepts in the preschool period and the evaluation of its effect.

The Design Phase of the Seels and Glasgow Model

The design phase of the Seels and Glasgow model covers the processes of "task analysis, instructional analysis, determination of objectives and benchmarks, teaching strategies, and delivery system". Each of the aforementioned phases and what was done in each phase are presented below.

In the process of task analysis, the answer to the question of "What is the work to be done?" is sought. In this process, the general tasks required to perform a specific work are listed (Seels and Glasgow, 1998). Accordingly, the works to be done for teaching scientific concepts by using interactive holographic material in the instructional process were listed by taking the preschool curriculum as a reference, and the purposes related to the subject were written down and the content was selected and organised. Prior to this process, documents on teaching scientific concepts with hologram technology were reviewed, including tasks and learning outcomes. In addition, experts and preschool teachers were interviewed, and observations of the learning environment were made as part of the preliminary study. The purposes and content contained within the scope of Earth and Space Sciences were structured. The purposes of this scope are provided below:

1. To be able to comprehend the basic concepts

2. To be able to understand the emergence phase of the incident, situation, etc.
3. To be able to comprehend the movements of planets and the results of these movements
4. To be able to realize the situations that might occur in the absence of planets
5. To be able to establish connections among the concepts that pertain to the same area of learning.

In the process of instructional analysis; in this step where the answer to the question of "What to teach" is sought, after determining the introductory behaviours of the student towards the lesson, the purposes of the lesson and the behaviours that the student is intended to gain in line with these purposes, are specified (Mendonca, 2003). The behaviours that are expected to be gained by the children at the end of the process in relation to the concepts determined in this step, were formed in line with the preschool programme and preschool experts' opinions. For instance, for the purpose of comprehension of the basic concepts contained within the framework of "Earth and Space Sciences", the children were expected to describe the characteristics of events and situations such as their names, colours, shapes, sizes, sounds, and purposes of use. In this context, a sample objective and the target behaviours that children are expected to acquire at the end of the process in line with this objective are as follows;
Objective 2: To be able to understand the formation phase of events, situations, etc., within the framework of Earth and Space Sciences.
Behaviors
• Explaining the phases of the formation of events and situations in detail
• Defining the differences in the formation phase of events and situations
• Finding possible causes for a situation where the outcome is obvious

In the process of determining objectives and benchmarks; the student who will gain the behavior, the behavior to be gained, characteristics of the environment and behavior criteria, are determined in this step. In this direction, the process was prepared according to the ABCD (Audience, Behavior, Condition and Degree) format and generated with objectives (Seels ve Glasgow, 1998).

In order to support children's academic skills, a rich classroom environment supported by visual materials appropriate for the developmental period should be created, and children should be encouraged to interact with these materials (Uyanık and Kandır, 2010). An interactive material set for the teaching environment was designed in this context. Similarly, the materials were designed with the following criteria in mind:
• Appropriate to the learning environment, curriculum, and developmental characteristics of children,
• Concretization of abstract concepts that are difficult and take time to observe in science teaching,
• Compatibility with current technologies,
• Can be reused multiple times,
• Cost-effective and ergonomic,
• Allowing children to take an active role in the process by having the opportunity to interact.

After the criteria were determined, it was decided to create an interactive environment with the Arduino set for designing the learning material. The environment was made interactive with sensors that appeal to different sensory organs.

In the process of instructional strategies and delivery, the content of the subject matter is involved, while strategies to be implemented and approaches to be taken are determined. In this step, it was decided, by taking children's developmental characteristics into account, to adopt an inquiry-based approach in line with the specified concepts (rain, snow, hail, etc.), Subsequently, in accordance with the inquiry-based approach, interactive scenarios were prepared in which the learner could be active in the process. In addition, during the activities, oral questions were asked to ascertain the knowledge of the learners.

Development Phase of the Seels and Glasgow Model

The development phase of the Seels and Glasgow model covers the processes of "material development and formative evaluation". Accordingly, the phases in the process and what was done within the scope of the research in these phases, are provided below.

In the process of material development; educational software is required to be developed by taking the principles of material preparation into account (Seels and Glasgow, 1998). In this step, the interactive holographic material set was designed. This material set is composed of interactive holographic material and a manual including scientific information.

The material should not only be prepared in accordance with educational material preparation principles but also fit the educational programme, have up-to-date and correct information, be clear and understandable, objective, and of educational quality. Moreover, the material must be motivational for the student and favourably affect student participation in the lesson. In order not to be exposed to any disruption during application, attention was paid to the material's sufficient technical quality and manual documents were prepared for their use. In this regard, the generation processes for holographic material and the manual are presented below in detail.

Generation of the hologram

The first version of the material was developed in the form of a single-beam reflection hologram (180 degrees) ; however, following the preliminary study performed with the preschool students, it was determined that the single-beam hologram gives the learner the sense of television (Figure 2). Therefore, it was observed that the use of a three- or four-beam reflection hologram is appropriate in the research process. However, it was found in the experiments that larger images are generated in three-beam reflection (360 degrees) than in four-beam reflection (270 degrees).

Figure 2. Hologram sample used in the first version of material

When the studies in the literature on three-beam reflection holograms were examined, it was observed that a pyramidal structure is used in this reflection technique. Moreover, it is mentioned that better images are obtained by using darker backgrounds (Kalarat, 2017). It was also observed that this reflection technique is used with small (5 inches) or large LCD monitors (Handani, Saputra, and Sari, 2017). In the study made with reference to the literature, it was determined to use a 20-inch LCD monitor in order to achieve a better image in the application environment.

In the reflection process based on the three-beam reflection hologram, first a prototype made of cardboard was formed, and then the image was tried to be reflected by using different glass sizes. As a result of the trials, a clear image of the size that may be easily observed by children was achieved in a three-beam reflection hologram performed by using a 2mm-glass. After determining at the end of the process that the reflection should be made with a three-beam technique and a 2mm-glass, the material was formed of wood, and the microcontroller and its connections were placed in it. Moreover, in order to obtain a clear image in the material, the black background was used in the places where the image would be reflected. By improving the quality of images in this way, the hologram image was presented to children in three different dimensions; the left, front, and right reflections. The prototype of the material and its latest version are presented in Figure 3.

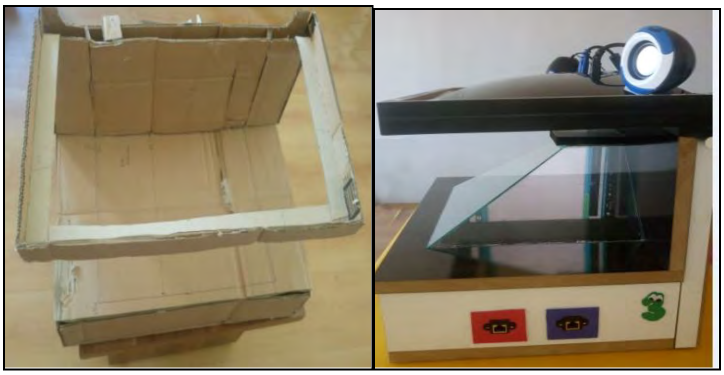
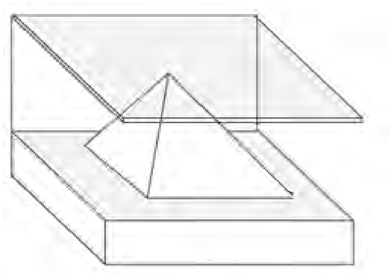


Figure 3. Prototype and latest version of the prepared material

Hardware and software structure of the hologram

In the teaching process, the learning approaches that enable children to get away from passive activities and be active in the process and that allow them to reach correct information by making inquiries must be adopted (Brenneman and Louro, 2008; Samarapungavan et al., 2008). Hence, the holographic material set prepared was designed in a way to allow for interaction with sensors and provided the opportunity for the children to take an active role in the process. In this environment generated in the above-mentioned way, the interaction was performed by using different sensors (for instance, an ultrasonic distance sensor, a potentiometer, etc.) addressed to different sense organs. The images in Unity 3D interacted with the digital data (location, angle, etc.) coming from the microcontroller, and the abstract scientific concepts that require a process to observe were tried to be presented with the sense of real-life experience via three-dimensional hologram technology. In the interactive holographic material prepared, sensor communication was performed with an Arduino Mega via a USB connection. The most important reason for preferring this platform is that it is open-source code and can provide enriched media to learners by way of different sensors. Moreover, Arduino is an affordable and easily accessible control card. Figure 4 provides the hardware and software structure of the interactive holographic material prepared in this way.



Hardware
Laptop, PC, etc.
20-inch screen
Speaker
Arduino Mega
Mega Sensor Shield
Sensors

Software
Unity 3D
Arduino Software (IDE)

Figure 4. Hardware and software structure of the interactive holographic material

The sensors in the sensor boxes prepared in a way to address the children (sun figure, lake figure, etc.) were run by plugging them into the analogue and digital entries on the material according to their characteristics. The sensors in the sensor boxes were transformed into different shapes in order to make them more interesting for children. Figure 5 provides some of the sensor boxes containing the sensors used during the activities.

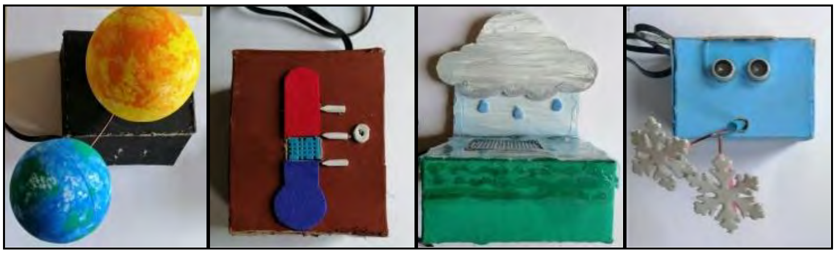


Figure 5. Some sensor box samples containing the sensors used during the activities

In the interactive holographic material, analog and digital entries were differentiated from each other by using sockets in red and blue colors, respectively. A digital and an analogue entry were placed in each of the three sections of the interactive holographic material —the front, right, and left sections, according to the perception of the sensors' data entry variables. In total, three sensors were used in each activity, being one sensor for each section of the material. These sensors vary according to the content of the activities. In the process, children were directing the content prepared according to scientific foundations by engaging in interaction with the help of sensors. 8 sensors in total were used during the activity process (button, joystick, ldr, potentiometer, heat and humidity sensor, switch button, ultrasonic distance sensor, rain sensor), and a sample image pertaining to the sensors and material used in the rain scenario is provided in Figure 6.

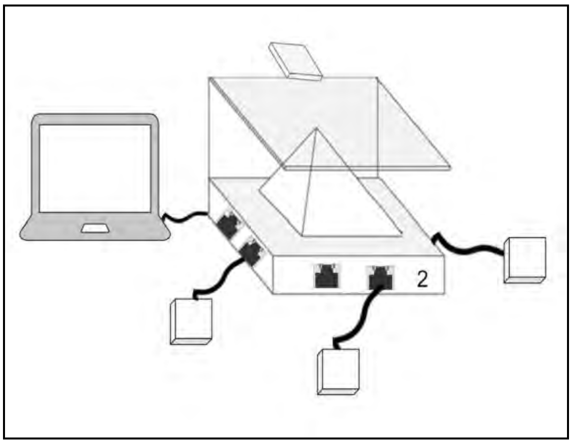


Figure 6 (a). The structure of the prepared interactive holographic material and sensors

Figure 6 (b). The real image of the prepared interactive holographic material and sensors

Potentiometer, one of the sensors used in the rain scenario, was transformed into a form that will attract children's interest with a blue box. The sun symbol on the box will be used to show sunrise. Accordingly, in line with the directive contained in the manual, the teacher asks the children to turn the sun in the 1st Section, i.e., the potentiometer, from the right to the left. With this interaction of children, the sunrise is shown in the hologram.

Generation of the manual

The teacher's manual, which was prepared for each preschool scientific concept determined within the scope of the research, was developed in line with scientific knowledge. The manual preparation proceeds in parallel with the operation of the material. By integrating questions pertaining to inquiry-based learning activities into the scientific knowledge contained in the manual, an environment was established where children tried to find the answers to these questions during the process. The activities conducted under the supervision of the teacher allow the children to ask questions, discuss, and reflect. Teachers were required to go through the manual to be prepared before the application.

Totalling 21 scenarios, 16 of which pertain to activities and 5 of which pertain to general activities, were present in the manual, which was given to teachers in order to guide them through the treatment of concepts. These activities included 'Rain', 'Snow', 'Hail', 'Fog', 'Rain, snow, hail and fog', 'Cloud', 'Lightning', 'Rainbow', 'Cloud, lightning and rainbow', 'Night', 'Day', and 'Night and day', 'Earth', 'Sun', 'Moon' and 'Earth, sun and moon', 'Spring', 'Summer', 'Fall', 'Winter', and 'Spring, summer, fall and winter'. This manual was designed to help teachers be aware of current misconceptions, if any, and proceed with the activities by addressing their lack of knowledge regarding scientific concepts. The scenarios in the manual were developed in phases in accordance with inquiry-based teaching and in line with scientific knowledge, with reference to the preschool curriculum published in 2013 and approved by the Ministry of National Education (MEB). Opinions were received from science experts regarding the accuracy of the manual and from preschool education experts on whether the information contained in the manual was prepared in accordance with the preschool level. Figure 7 presents a cross-section of the night scenario, which is among the scenarios contained in the manual. In light of the mentioned scenarios, scenes for the interactive hologram-supported material set were created with the Unity software, and the interactions in the scenes were made possible through sensors.

Gece (10.etkinlik)

- Çocuklar sizce gece nasıl oluşur? çizerek gösterir misiniz?
- Gece gökyüzünde neler vardır?
- Peki dünya, güneş ve ay deyince aklınıza ne geliyor?
- Dünya, güneş ve ay hareket eder mi? Ederse bu hareket nasıldır?
- Dünya, güneş ve aydan hangisi daha büyük, hangisi daha küçüktür?

Soruları sorularak çocukların fikirleri alınır, not edilir ve tartışılır.

Şimdi bir dünya ve güneş düşünün denir.

"Hadi şimdi çocuklar dünyayı kendi etrafında hareket ettirelim." denir. Çocuklardan 1. Bölmede yer alan dünyayı sağdan sola doğru döndürmeleri istenir (Potansiyometre kullanılmalı-AP2). *Her etkinlikte Potansiyometre sıfırlanmalı*

Yönergesi ile çocukların uygulama yapmalarına fırsat tanınır.

Hologramda dünya, güneş ve ayın görüntüsü gelir ve dünya dönmeye başlar.

- Peki bunlardan hangisi dünya olabilir? Peki sizce hangisi güneş? Diğeri ne olabilir?

Çocuklardan dünya, güneş ve ay cevabı beklenir. Ya da dünya, güneş ve ay olduğu ifade edilir.

- "Çocuklar dünyamızı aydınlatan sizce ne olabilir?" denir,
- Peki dünya kendi etrafında döndüğü için güneş dünyanın tamamini aydınlatamıyor, aydınlatamadığı bu kısımda sizce ne olabilir?

Soruları sorulur ve çocuklar tahmin etmeye teşvik edilir.

Figure 7. A cross-section of the night scenario from the manual

The manual specifies when children must use which sensor, and this directive was given to children under the supervision of the teacher and in accordance with the course of the scenario. In addition, sensor boxes were denominated according to the sensor's characteristic (analog or digital), the name of the sensor, and the section it is located in. These names were added to the directives regarding the sensor that are contained in the manual. For example, the rain sensor that would be mounted in the first section was called AR1. Moreover, this abbreviation was placed under the sensor boxes as well, to facilitate matching the sensor and holographic material.

In the formative evaluation process, the focus is on the interim evaluations in the product development process and whether this evaluation process advances in accordance with its purpose. Accordingly, decisions are made regarding what shall change in the process and what shall be added to the process (Seels and Glasgow, 1998). The material set prepared as of the end of the process was presented to Computer Education and Instructional Technologies experts and Science Education and Preschool Education experts, and their opinions were received. The opinions received from Computer Education and Instructional Technologies experts are given in Table 1, opinions received from Science Education experts in Table 2 and opinions received from Preschool experts in Table 3. The experts were coded according to their fields of expertise. Accordingly, Computer Education and Instructional Technologies experts were coded as EC1...EC4, Science Education experts as ES1...ES3 and Preschool experts as EP1 and EP2.

Table 1. Opinions received from Computer Education and Instructional Technologies experts regarding the material set

Themes	Codes	Computer Education and Instructional Technologies Experts			
		EC1	EC2	EC3	EC4
Upgradability	Ease of movement			✓	
	Wooden boxes		✓		
	Intervention of the teacher in the display	✓			
	Renewal of sensor connections	✓		✓	✓
Ease of use	Running under the guidance of a manual	✓	✓	✓	✓
	Having a detailed manual prepared	✓	✓	✓	✓
	Student communicates with a single sensor		✓		✓
	Numbers designated to sensors and the manual		✓	✓	✓
Suitability for students	Designed in accordance with the target audience	✓		✓	✓
	Practicable for individuals and groups	✓	✓	✓	✓
	Sensors designed in a way that children can understand			✓	✓
Error-free display of information	Clear images	✓	✓	✓	✓
	Images proceed in accordance with the manual	✓	✓	✓	✓
Availability of supportive material	Paying attention to the animation stream	✓			✓
	Paying attention to cognitive load	✓			
	Being interesting or motivating			✓	✓
	Addressing different senses	✓	✓	✓	✓
Allowing children to interact	Sensor-supported hologram	✓	✓	✓	✓

With respect to the opinions received from Computer Education and Instructional Technologies experts via the material evaluation form, the experts mentioned deficient aspects of the material only under the theme of upgradeability. EC1, EC2 and EC3 stated that in order not to experience disruptions due to transmission in the application phase of the connections made to the material, sensor connections must be renewed. In addition, some suggestions were made for improvement of the material, indicating that the material is heavy but should be easy to move (EC3), that the sensor boxes should be made of wood, not carton, for their durability (EC2) and that teachers must be allowed to intervene in the available displays (EC1).

EC1, EC2, EC3 and EC4 mentioned that the interactive holographic material was easy to use. All four of the Computer Education and Instructional Technologies experts favourably evaluated the preparation of activities in detail and their performance in accordance with a manual. Moreover, the fact that the numbers written under the sensor boxes are also available in the manual was found to be beneficial for the sake of sensor placement. Computer Education and Instructional Technologies experts referred to the fact that the material is appropriate for individual and group studies. Whereas the child proceeds in accordance with the directives in the manual, lending the children the opportunity to intervene in all 3 sensors for the completion of the activities ensures group study. Also, having clear images in the hologram and their flow in parallel with the manual were found critical by all the experts with respect to the process of displaying the information faultlessly. On the other hand, the experts (EC1, EC2, EC3, EC4) mentioned that the material was supported by the fact that it addresses different sense organs. In addition, it was stated that the holographic image was supported by sensors and that it was favourable for the children to interact with the material in this way.

Table 2. Opinions received from science experts in relation to the material set

Themes	Codes	Science experts		
		ES1	ES2	ES3
Presentation of information	Presentation of information incrementally in the manual	✓	✓	✓
	Giving concepts first singly and then collectively	✓	✓	
	Concepts flow based on similar scenarios and the principle of spirality	✓	✓	
Content matches scientific knowledge	Visualising the concepts in a way that children can understand	✓	✓	✓
	Structuring concepts in accordance with scientific content	✓	✓	
Division of concepts into appropriate sections	Content items being prerequisites for each other	✓	✓	✓
	Placing content incrementally	✓	✓	✓
Material supports the teaching of concepts	Supports the permanence of information	✓		
	Interaction allows children to learn through practise and experience	✓	✓	✓
	Addressing different senses	✓		✓
	Learning concepts through internalisation	✓		
	Being able to establish relations among concepts			✓
	Concretizing abstract concepts		✓	✓
	Being three-dimensional and interesting		✓	✓
Material develops inquiry skills	Questioning the situation given in the scenarios pertaining to the concept by using hints and variables	✓	✓	✓
	Observation of the process with the answers given to the questions asked in the manual	✓	✓	
	Questioning under what circumstances the concept would occur	✓	✓	✓
Material develops scientific process skills	Integration of questioning process and scientific process skills in the manual	✓	✓	✓
	Identification of scientific process steps in the generation of the manual		✓	
	Advancing the hologram under children's control		✓	

In presenting their opinions on the material evaluation form, all three Science Education experts pointed out the importance of having the information in the manual placed incrementally. Similarly, having the concepts in the manual first listed individually and then collectively shows that the information is provided in a logical order. All three experts mentioned that the concepts were formed in a way that children can understand, and ES1 and ES2 stated that the concepts were structured in accordance with scientific content. All experts agreed that incorporating the content into the activities incrementally and in such a way that each one is a prerequisite for the next was appropriate. The experts stated that the interactive holographic material set would support the learning of concepts by children because it allows them to learn by practise and experience, and concretizes the abstract concepts in a three-dimensional and interesting manner. The experts were of the opinion that the material is effective in another aspect as well, namely its ability to develop children's questioning skills. It was found to be significant that, for the sake of developing children's questioning skills, the situation given in the scenarios pertaining to the concept is queried by using hints and variables (ES1, ES2 and ES3), the process is observed through the answers given to the questions asked in the manual (ES1 and ES2) and it is questioned under which conditions the concept would occur (ES1, ES2 and ES3). Moreover, all of the experts stated that the integration of scientific process skills with the questioning process in the scenarios contained in the manual would have a positive impact on the development of children's basic scientific process skills.

Table 3. Opinions received from preschool education experts in relation to the material set

Themes	Codes	Preschool Education Experts	
		EP1	EP2
Use of clear and understandable content	Availability of phrases and visuals that fit children's developmental characteristics	✓	✓
Suitability for students	Ensuring active participation of children in the process	✓	
	Concretization that fits the developmental characteristics of children		✓
	Practicable for both individuals and groups	✓	✓
Having the nature of supportive material	Active use of scientific process skills	✓	
	Learning by discovery for children in accordance with the foundation of scientific topics	✓	
	Guidance is provided in the manual in order to address misconceptions	✓	
	Concretization of abstract concepts		✓
Having attractive content	Being related to daily life and natural events		✓
	The topics selected allow for questioning by children	✓	
Being motivating for children	Being a different material that they would come across for the first time	✓	✓
	Interaction of children with the material	✓	✓
Allowing children to interact	Learning occurs for children through practise and experience in the process		✓
	Children's achievement of the result by using the material and by giving answers	✓	
Addressing different sense organs	Supporting the process visually	✓	✓
	Supporting the process aurally	✓	✓
	Supporting the process tactually	✓	✓

In providing their opinions regarding the material set, preschool education experts favourably evaluated the fact that the material set involved phrases and visuals appropriate to the developmental characteristics of children and that the content is clear and understandable. Similarly, EP1 and EP2 stated that the material set was designed to enable both individual and group applications. In addition, under the theme of appropriateness for students, they said that the material increased the active participation of children in the process (EP1) and that the process was concretized based on children's developmental characteristics (EP2).

They mentioned that, with its aspects of supporting the learning process and arousing interest, the material set is fit for use. Under the theme of being a supportive material, they stated that scientific skills may be actively used in the process, the material ensures children learn by discovery in accordance with the foundation of scientific topics, the manual is a guide for addressing misconceptions, and the material helps concretize abstract concepts. Under the theme that the content arouses interest, the experts emphasise that the content is related to daily life and natural events and that the selected topics allow children to ask quesitons. Both of the experts mentioned that the material was designed to be practicable for both individuals and groups, and that as it is a different material that children would come across for the first time and since they would interact with the material, it would support motivation. Moreover, both of the experts favourably evaluated the fact that the material addresses the visual, aural, and tactual senses, in other words, that it supports different sense organs.

In line with the evaluations received from all the experts regarding the material set, for the purpose of carrying out the relevant process in a more sound manner, the material and the manual were provided to different preschool teachers other than the children's own teachers, and the former were asked to examine them. Afterwards, according to the feedback given by the experts, the sensor connections were renewed, and, in line with the opinions of preschool teachers, some additional questions were added to the manual, thereby finalising the material set.

Implementation and Evaluation Phase of the Seels and Glasgow Model

This phase of the Seels and Glasgow model covers the processes of "implementation and maintenance" and "summative evaluation". What was done during these processes is presented in the relevant sections below.

Implementation and maintenance process, this step, where the designed material is implementedand its maintenance is performed and checked, is not the main implementation phase of the relevant material. The principal purpose of this process is to finalise the developed material by checking it for the main application (Seels and Glasgow, 1998). The material set was applied for 10.5 weeks (two events per week) in total in 21 activities ('Rain', 'Snow', 'Hail', 'Fog', 'Cloud', 'Lightning' etc.) within the framework of the pilot scheme, and solutions were brought to the problems found as a result of this practise. A cross-section of the problems and solutions experienced during the activities in the pilot scheme are presented in Table 4. When Table 4, which includes the problems and solutions identified in the interactive hologram-supported material set in the pilot scheme, is examined, the cables used in the sensors in all activities were converted into a single cable, and the cables were soldered to the sensor in order to prevent technical problems caused by the connection problem experienced in the process. The images and sounds in the 3D designs in the activities were revised to help children understand the content more clearly. In addition, additional questions and instructions were added to the manual, which was prepared in accordance with the scientific content, both to support the teacher's learning process and to facilitate the children's understanding of the related activities.

Table 4. A Cross-Section of Problems Identified in an Interactive Hologram-Supported Material Set and Solutions Produced

Activities	Identified problems	Solutions
Rain	The sudden encounter of the clouds with the cold was not clearly understood.	When the clouds encountered the sudden cold, the color of the clouds was darkened, and the sound of cold air was added.
Snow	There were problems with the sensors due to loose cables.	The cables used in the sensors were converted into a single cable and soldered to the sensor.
Hail	The transformation of small raindrops into ice crystals was not clearly understood by the children; the transformation into ice crystals was only briefly visible on the screen.	The scene where small raindrops turn into ice crystals was extended to allow children to make clear observations.
Fog	The instruction in the manual for children to draw the cloud before the fog was misplaced.	The instruction to draw the cloud before the fog was removed from the manual, and only the formation of the fog was asked to be drawn. But the question "How are clouds formed?" was not addressed.
	The statement "Evaporating water encounters sudden cold near the Earth's surface" in the manual was not emphasized by the teacher.	The statement "encountering sudden cold near the Earth's surface", which should be emphasised in the manual, is highlighted in red.
Cloud	The children did not understand why the clouds were moving.	The sound of wind was added to the scene where the clouds were moving. It was added to the manual that the clouds move because of the wind.
Lightning	In order to improve the activity, the teacher had to ask additional questions during the activity.	Additional questions asked by the teacher during the activity were added to the manual after receiving expert opinions. Example: The questions "Do we first hear the sound or see the

		light of the lightning?" and "So, what could cause these surges?" and "Did the temperature go up or down?" were added.
Rainbow	Although it was observed that the rainbow consists of seven colours, the students did not learn which colours they are.	Although the colours of the rainbow are displayed in the manual, the name of each colour of the rainbow was added to the manual to give instructions to the teacher. It was also emphasised that the refraction of sunlight creates seven colours.
Night	It was determined that the answer to the question "Which of the Earth, the Sun, and the Moon is the largest?" and "Do the Earth, the Sun, and the Moon move?" should be asked earlier, according to the course of the activity.	"Which of the Earth, the Sun, and the Moon is the largest?" and "Do the Earth, the Sun, and the Moon move?" were included alongside the first questions in the manual.
Day	It was determined that the answer to the question "Which of the Earth, the Sun, and the Moon is the largest?" and "Do the Earth, the Sun, and the Moon move?" should have been asked earlier in the activity.	"Which of the Earth, the Sun, and the Moon is the largest?" and "Do the Earth, the Sun, and the Moon move?" were included alongside the first questions in the manual.
The Earth	In order to improve the activity, the teacher had to ask additional questions that are not included in the manual during the activity.	It was observed that the questions asked by the teacher helped students with comprehension. For this reason, additional questions asked by the teacher during the activity were added to the manual after receiving expert opinion. Example: Where in the world are the colours green and blue found?
Spring	In the hologram, the passage of the birds was fast, and their sounds were not clearly audible.	The passage of birds in the hologram was made continuous, and the sound of the birds was amplified.
Summer	Although it is not included in the manual, the teacher made a connection between the duration of solar radiation and the darkening of the sky in order to make it more understandable.	It was observed that the connection established by the teacher helped students with comprehension. For this reason, the statement used by the teacher during the activity was added to the manual after receiving expert opinion. Example: The more sunlight we get, the later it gets dark.

During the activities, it was observed that taking an active role in the process with the help of sensors and seeing the existing images change and hearing the sounds in the hologram were remarkable for the children. In addition, the fact that children would experience hologram technology for the first time provided them with a remarkable, fun, motivating, and intriguing environment.

In the summative (consequential) evaluation process; data are collected after application, gathered data are interpreted, and it is determined in line with these data to what extent the objectives set at the beginning of the process are achieved. At this stage, the opinions of Computer Education and Instructional Technologies, Science Education and Preschool Education experts were again sought to come up with a final decision on whether the material set was appropriate for the study group and the objectives. And in the diffusion phase, the innovations decided to be made are put into practise and disseminated. In this respect, in the diffusion phase, a holographic material set was allowed to be used in the classes of 5th degree and over in preschool institutions.

Discussion and Conclusion

When the instructional process designed based on Seels and Glasgow instructional design model is assessed, structuring of disrupted aspects within the process by the model's nature, makes a positive contribution to the material set. Gülhan ve Karsak (2014) and Şakar (2008) mentioned the fact that the computer-assisted instructional design made according to the relevant model increased the academic successes of students and process performances. Moreover, Uzunboylu and Koşucu (2017) stated that, being open to change and improvement, this model has a critical role in the achievement of the objectives set and the material selected. In this context, the process of designing and assessing the effectiveness of an interactive holographic material set is structured in line with the Seels and Glasgow model.

When the problem analysis process of the Seels and Glasgow model is focused on, it is known that the period in which children learn basic concepts is pre-school and that the concepts are acquired through the activities performed by the child or the experiences gained (Fleer, 2009; Tu and Hsiao, 2008). In this respect, it is important to make room for real-world-based materials in educational environments to allow children to make sense of items such as scientific phenomena and concepts correctly in their minds. There are conclusions in the literature that the hologram technology that allows for the display of objects from different angles (Aina, 2010), facilitates comprehension of scientific topics existing in real life and can be used in teaching concepts (Mnaathr and Basha, 2013), and that its use would be effective in the instruction of science (Olson, 2013). Moreover, the reason why materials are preferred to be prepared in three-dimensional form these days (Işık, Işık and Güler, 2008) is the fact that the real world is three-dimensional and that abstract concepts may be concretized by using three-dimensional images (Barkhaya and Halim, 2017; Eschenbrenner, Nah and Siau, 2008; Ghuloum, 2010). Generation of three-dimensional, lifelike images with the developed material set would contribute to the concretization of the difficult concepts that require a process as well as the abstract concepts. Similarly, experts state that the material in question can be used to concretize abstract concepts and support the teaching of concepts.

If the instructional activities to be carried out by using the interactive holographic material set, are designed in the light of scientific knowledge and in accordance with inquiry-based learning, this would contribute to the development of children's questioning skills. Experts also emphasise that questioning the concepts given in the manual by directing questions to children and questioning the situations in which the concept will occur will be effective in the teaching process. Similarly, it was frequently emphasised that the inquiry-based learning activities contribute to the development of students' scientific process skills (Stout, 2001; Sullivan, 2008; Şimşek and Kabapınar, 2010; Wu and Hsieh, 2006; Wu and Krajcik, 2006). Furthermore, the scientific activities prepared for children must be supported with scientific process skills, allowing them not only to learn the concepts and events but also to come up with their own knowledge (Ward, Roden, Hewlett and Foreman, 2008). However, Ergazaki and Zogza (2013) stated that preschool teachers faced challenges in performing basic scientific process steps in the activities they conducted. Therefore, it may be asserted that the manual, a guide for teachers, includes scientific information and questions aiming to develop children cognitively at the basic level, which significantly support this process. Similarly, experts underline that the manual can be used both to eliminate misconceptions and to support science process skills.

During the design process, the interaction of the teaching process with the sensors in the material set was positively evaluated by the experts. Similarly, it was found that hologram technology is used to teach real objects by being supported with different tools (Walker, 2012) and that this technology enables to establish three-dimensional interaction (Barkhaya and Halim, 2017). It was also determined in the literature that, the interaction ensured with sensors connected to the Arduino helped students understand and comprehend the lesson better (Hertzog and Swart, 2016); rendered students more active (Jawawi et al., 2015) and had a positive impact on their putting theories into practise (Slåttsveen et al., 2016). In this way, it is possible to support the learning process by allowing students to learn through practise and experience with the help of sensors placed in the material set. Moreover, the learning media supported by sensors provide the opportunity to activate different sense organs in learners (Hanson and Shelton, 2008). It is known that the more the learning activity is structured in a way to address more than one sense organ, the more permanent the learning becomes and the slower the oblivescence occurs (Dale, 1969). Accordingly, it is considered that the visuals in the material set that were prepared using Unity 3D may address different sense organs of children, together with the sounds integrated with these visuals and the sensors used.

The information being incorporated in the manual, from simple to complex and from known to unknown, is of importance for the sake of the logical presentation of information. The experts also emphasised that the scientific content in the manual as well as their presentation with phrases and visuals in the interactive holographic material that fit the developmental characteristics of children would support the learning process. Technology-assisted materials prepared in accordance with children's developmental characteristics contribute to their academic successes in the fields of language (Liu, Tan, and Chu, 2010), reading and writing (Ihmedieh, 2010; Judge, 2005), mathematics (Own, Cai and Hung, 2022) and science (Daugherty, Dossani, Johnson and Oguz, 2014). In addition, the fact that the content was included in the activities incrementally and in a way that they would be preconditions for each other was found to be appropriate by the experts. NAEYC (2012) pointed out the importance of having the language used in the process in a way that children can understand and the presentation of new information by establishing the connection with previous information for the permanence of the learning process. In this case, it is possible to claim that the material set was duly prepared, supported by accurate directives, and developed in accordance with its purpose by establishing connections between the manual and the hologram. In addition to all these positive aspects of the material set, experts in the field of CEIT expressed some reservations about the formative assessment process of the Seels and Glasgow models. One of these reservations is that the sensor connections should be renewed and the teacher's intervention on the existing screens should be made possible in order to avoid disruptions during the implementation phase due to the transmission of the connections to the material. In addition, since the material is heavy, it was also suggested that the sensor boxes should be made of wood instead of cardboard for durability and easy transportation. In this context, in interactive hologram-supported materials, sensor connections were renewed in line with expert opinions, and it was made possible for the teacher to intervene on the screen. However, no improvements could be made due to the heavy weight of the material and the high cost of easy transportation. Similarly, making the sensor boxes out of wood would create extra weight, so they were left as they are.

In the implementation and evaluation process of the model, it was understood that the material set was easy to use, interesting, and motivating. Aino (2010) states that the hologram technology is an interesting technique used for displaying an imagined object from different angles and that this technique could be used to solve problems in education. Accordingly, since the children would experience the generation of concepts in the material set for the first time and as they would interact with the material, this might provide children with an interesting, fun, and motivating environment.

Suggestions

As it presents concepts in a real-like, three-dimensional manner, supports the process of structuring concepts in children's minds, and allows them to learn by practise and experience, this material set may create an environment that would enable children to learn by playing an active role in the process. Usually, scientific concepts are hard for children to grasp, because they are abstract, and children are more prone to concrete phenomena at this stage. Thus, the interactive holographic material set may be preferred, especially to concretize abstract concepts. Furthermore, this material set may also be used to address the lack of materials in the teaching process of scientific concepts during the preschool period.

The fact that the material set is connected via cables and that it cannot be controlled remotely may be a disadvantage for teachers who are adapting to new technology. Accordingly, adding a remote-control feature to the hologram technology by using Bluetooth technology may be a useful update to allow for teachers' remote control. Moreover, in order to make the material more ergonomic, it may be made of lighter materials such as polycarbonate, polymer, and mica. Similar materials may be used to enhance the strength of the sensor boxes.

The developed material set was designed for preschool children of 60 months and above. It may be proposed to the researchers who will conduct studies in this field to extend the scope of application of the material set in a way to include other levels. In addition, researchers may prefer the Seels and Glasgow model, which is open to revision and change to develop quality and permanent products.

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Author's (s) Contribution Rate

The doctoral dissertation from which this article was produced was written by the first author under the supervision of the second author. The entire manuscript was examined by the second author during the article preparation process, and any necessary changes and corrections were made before it was ready to be submitted.

Conflicts of Interest

All authors declare no competing interests.

Ethical Approval

Research permit approval was received for this study from the Giresun Governorate Ministry of National Education (Date: 23.07.2018, Issue: 29409993-605.01-E.13656345)

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