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Activity Design for Secondary School Students' Modeling Skills: A Design-Based Research*

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Abstract

Models and modeling process have been used for many years in science education courses, which contain many concepts that are difficult to understand and abstract. With the help of models, students improve their knowledge level related to the subject and realize learning by hands-on activities in the production process. In the model production process, they perform some behaviors called modeling skills. The purpose of this study is to design computer-based activities to develop students' modeling skills. In this context, design-based research method was used in the activity development process. Activities were developed within the framework of a total of two cycles. Within the scope of the first cycle, drafts of the activities were made, and the activities were transferred to Adobe Flash environment with field educators and computer experts. In the first cycle, the activities applied to 11 middle school students and necessary arrangements before the second cycle, and after the second cycle, the activities were finalized. At the end of the development process, a total of six computer-based activities were achieved. With the help of these activities, various applications can be made for the students' related modeling skills. In this way, students can produce better models and develop their level of conceptual knowledge about science lesson subjects.

Keywords
Science education
Modeling skills
Activity development
Computer activity
Design-based research

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INTRODUCTION

It can be thought that it provides a good environment for the use of models and modeling studies, since science courses contain abstract and complex concepts. In this way, students can comprehend the concepts and phenomena of the complex or micro-macro worlds that are difficult to understand in the subjects they have learned, by modeling and modeling processes more easily (Treagust et al., 2002).

The model is the totality of the conceptual structures existing to interpret complex systems in the human mind and their external representations (Harrison, 2001; Lesh & Doerr, 2003; Treagust et al., 2002). It is stated by the researchers that models that allow new discoveries from known phenomena in scientific knowledge production contribute to scientists (Güneş et al., 2004). These advantages have led to the frequent use of models in science classes.

Modeling activities are:

- Expand to students' subject matter knowledge
- Enables students to specialize in understanding, defining, and visualizing of scientific facts (Lehrer & Schauble, 2006; Schwarz & White, 2005)
- Produces better solution skills for new problems faced by students
- Develop a deeper understanding of the subject (Lehrer & Schauble, 2005; Wynne et al., 2001).
- Ensures that science is compatible with epistemological purposes
- Develop higher level ideas about scientific entrepreneurship (Schwarz & White 2005; Windschitl et al., 2008).

It should be well planned top re-modeling process to fully realize the above-mentioned advantages of modeling activities. However, just as individuals need scientific process skills to perform processes such as experimenting, collecting data, and analysing these data, they also need some skills when performing modeling activities. These skills should be acquired at a certain level before the modeling activities. This will enable the modeling activities and the model to be developed because of the process to serve its purpose more accurately. These skills identified by Bülbül (2019) are presented as follows:

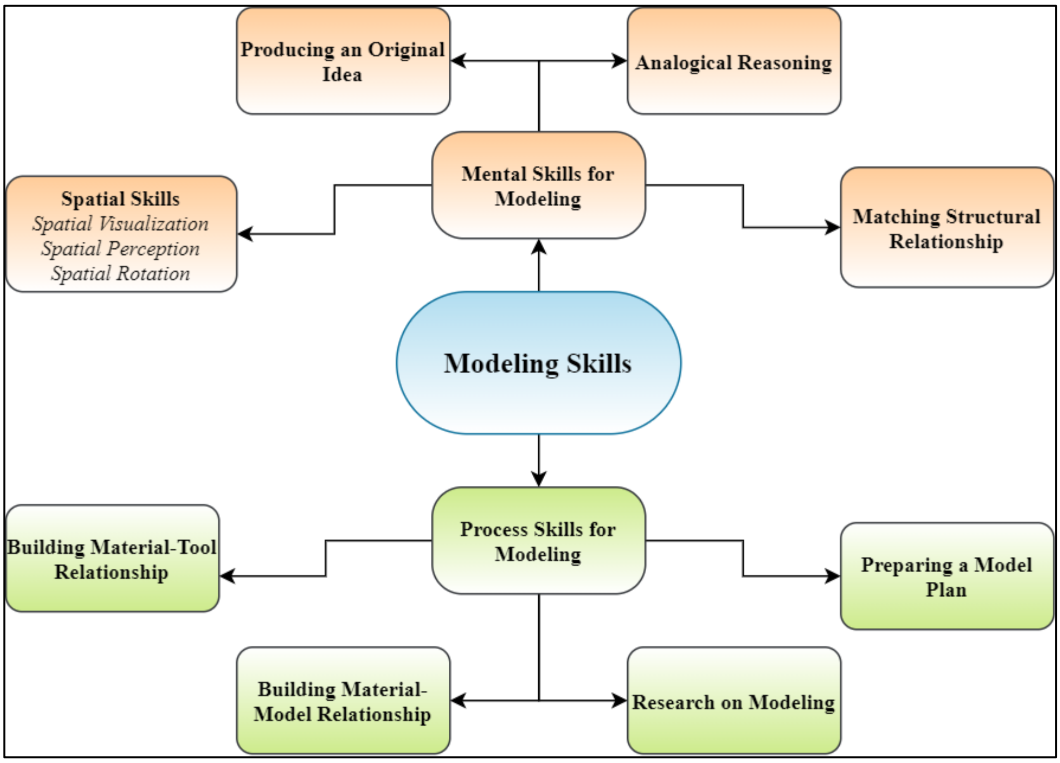

Figure 1. Modeling skills

Modeling skills, mental and process skills can be seen in Figure 1. It is stated that the mental skills for modeling are mostly transformed and their views from different angles such that spatial visualization, spatial perception, spatial rotation, produce an original idea, analogical reasoning and matching structural relationship. Process skills for modeling are building material-tool relationship, building material-model relationship, research on modeling and preparing a model plan.

The development of students' modeling skills is effective in learning science education conceptually. Considering that one of the main objectives of modeling is to embody abstract concepts in students, the development of these skills helps to comprehend the issues that are not understood by the students. One of the methods of developing these skills is the development of computer-based activities.

It is emphasized that the importance of computer-based activities in the development of skills in science education in the literature (Barab et al., 2000; Frederiksen et al., 1999; Hung & Lin, 2009; Méheut, 2004; Sins et al., 2005; Valanides & Angeli, 2007; Yılmaz, 2012; Yurt, 2011). In other words, teaching process through computer-based activities positively affects students' critical thinking, scientific process skills and creative thinking skills. Considering that the modeling stage of the students is a teaching process, it is thought that computer-based activities will also be effective in modeling skills. For example, when describing building material-model relationship skills, the presence of active buttons and simulations showing which material will work in what kind of computer-based activities will help students understand the skill better.

In addition, computer-based activities and modeling in this way facilitate the understanding of theories and concepts by processing complex data. In this way, the scientific process becomes more active and complex facts are understood (Metcalf et al., 2000; Raghavan et al., 1998; Raghavan et al., 1995; Stratford, 1997; White, 1993).

It is seen that technology has a positive effect on modeling-based science education in the process. For instance, Barab et al. (2000) aimed to the effect of three-dimensional modeling process on computer in teaching solar system while teaching basic astronomy subjects. For this purpose, researchers applied classroom activities, make observations during these activities and the video is recorded to 19 university students for two semesters. Throughout the application, each student was able to follow the directions in computer activity individually and produce a project to model astronomy events. In addition, interviews were conducted with the students before and after the application. As a result of the research, Barab et al. (2000) found that computer-aided three-dimensional modeling contributed positively to conceptual understanding and that students were able to express the relationships between models and the reality represented by these models at a good level. Similarly, Valanides & Angeli (2007) conducted research on the teaching and learning of scientific models using computer-aided modeling. In this study, they put forward their efforts to support prospective elementary school teachers about the learning and teaching of scientific models and investigated the effect of this situation on prospective elementary school teachers' comprehension levels. At the end of the study, Valanides & Angeli (2007) stated that teachers need extensive learning experiences in order to reach a comprehensive understanding of scientific modeling process in science. Yılmaz (2012) conducted a study called the comparison of the effects of computer-based modeling and physical modeling on the spatial abilities of ninth grade students and their understanding of the crystal structures of ionic compounds. In this study, he stated that computer-based modeling programs and physical modeling are effective on students' comprehension levels.

Purpose of the tudy

As a result, it was observed in the related literature that studies conducted on computer-based activities positively affected students' attitudes, behaviours, modeling abilities and modeling processes towards modeling. This shows that if students are expected to perform modeling skills or conceptual learning, computer-based activities should be included as much as possible. In other words, it is seen that one of the most effective methods of developing modeling skills in students is the development of computer-based activities. Therefore, the aim of this research is to design computer-based activities to develop to students' modeling skills.

METHOD

Since the aim of the research was to develop computer-based activities to develop modeling skills of students, design-based research method was used. Design-based research methodology is based on the systematic identification and strengthening of learning elements (Cobb et al., 2003, Lesh & Sriraman, 2005). In design-based research, the process is to develop a design for solving a determined problem, implementation of this design, evaluation of this design, to continue in a cyclic process by applying repeatedly during the evaluation period (Gravemeijer & Cobb 2006; McKenney & Reeves 2013; Wang & Hannafin, 2005).

Computer-based activity for skills in research was developed in two cycles in line with the design-based research process. The process involving these cycles is as follows (Bülbül, 2019):

- Creating drafts of activities
- Examining drafts with field experts and computer experts
- Creating drafts in Flash based computer environment
- Implementation of the developed activity (first cycle)
- Examining the data obtained from the first cycle and making the necessary corrections
- Implementation of the activity after revisions
- Finalizing the activities (second cycle)

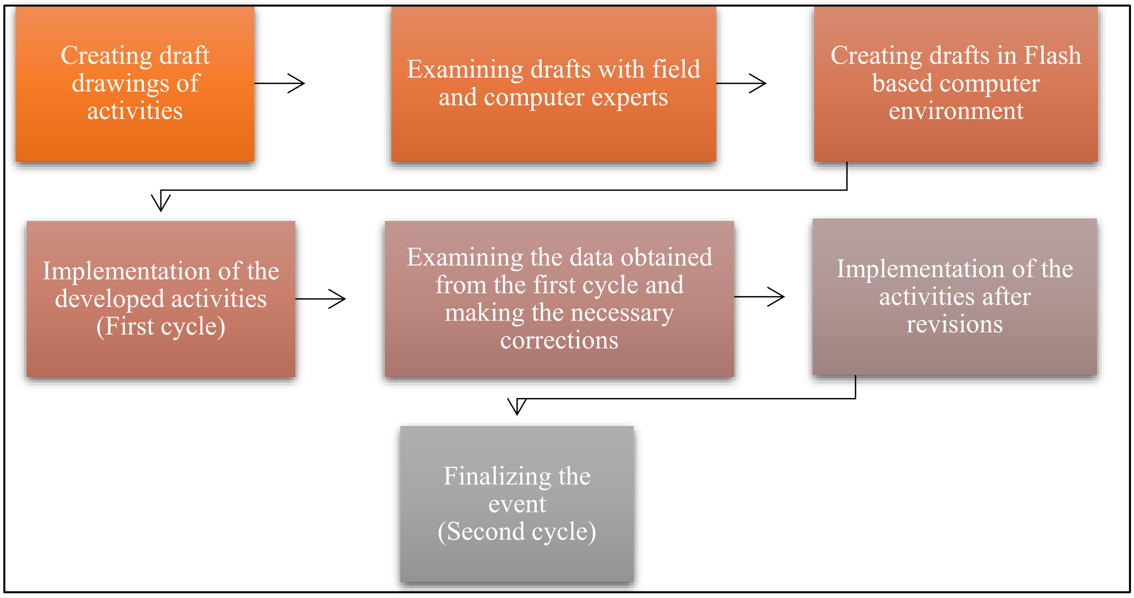

Figure 2. Designed based research process

Conducting the First Cycle

The first cycle of the activity development phase of the research is the preparation of the design with field experts and computer experts, presenting this design to the students and evaluating the feedback received. First, the drafting of skills development activities started with the creation of drawings. The sketches were drawn on paper and examined by both field experts and computer experts and finalized for the creation of a computer environment. Adobe Flash program was used to prepare drafts as computer activity. The developed computer activities were applied to 11 seventh grade students in a secondary school in the Black Sea Region to complete the first cycle.

Conducting the Second Cycle

In the process following the completion of the first cycle of the research, the second cycle started with the necessary corrections because of the feedback obtained from this cycle. In this context, some adjustments were made both in terms of design and content with the regulations that prevented the correct operation of the activities.

Explanations on these corrections are presented under the title of findings. The second cycle was also applied to the same students and the activity development process was completed at the end of this cycle within the scope of evaluation of the feedback obtained and the activities were finalized.

Research Group

In this study, 11 seventh grade students were studied in a secondary school in Trabzon in the fall semester of 2016-2017 academic year during the computer-based activity to develop modeling skills. After the activities were developed, the necessary revision procedures were completed, and the second cycle of the design research was carried out with the 11 students in the spring semester of 2016-2017 academic year. The computer-based activities are finalized because of this application.

Data Collection Tools

In the study, questions were asked to students during the process to develop to the computer -based activities. The aim here is to test the development objectives and working mechanisms of the activities, identifying points that are not understood or cause misunderstanding, identifying the parts that need to be developed or identified as missing. Therefore, the students were asked the following questions and the data were collected during the activities.

- How is the layout of activity? Does it have a complicated structure to you? What are your recommendations for the organization of activity?
- Have you encountered something that you detected when you were using computer activity? What was your problem?
- Are there sentences you do not understand in the texts written in computer activities? What are the mixed words you don't understand?
- Were there any visuals and figures in computer activities that were not understood? Size, colour, location and so on. What are your suggestions on issues?
- How were the computer activities lasted? Were there any parts of you that were boring you during long-term activities? What do you recommend for their elimination?

Researchers have been in constant communication with the students during the implementation of the computer-based activities with this process. All students who applied the activities were contacted and questions were asked during each activity. The students were asked to inform the researcher about the parts they could not understand or had difficulty about developed activities. The most important thing that most of the students stated isis that there is no implementation directive in the activities developed. The researcher realized that it was difficult for the students to comprehend the activities without the implementation instructions and to carry out them in accordance with the purpose. However, another situation that is noticed during the development of the activities is that the students indicate that the buttons and shapes are not in the desired structure as designed during the development process. These questions in the activities were identified with the questions about the non-working parts directed to the students and these problems encountered in the computer-based activities were overcome with the help of field experts. Finally, it was seen that students had difficulty in understanding some statements. These activities were finalized with a researcher in the field of Turkish education.

The computer-based activities were finalized in the second stage of the study. In this cycle process, the researcher formed the field notes considering the application methods of the students' activities, understanding levels, modeling skills, etc. features. The researcher visited the student groups and took notes among the application processes.

FINDINGS

In this study, which was conducted with the aim of developing computer activities aimed at the mental and process modeling skills of secondary school students, computer-based activity of each skill was developed. Table 1 is given to the names of the computer-based activities and what skills it aims to develop.

Table 1. Computer-Based Activities

Activity ID	Activity Name	Modeling Skill
1	Analogical Puzzle	Analogical Reasoning Matching Structural Relationship
2	Gift Prediction	Produce an Original Idea
3	Cell	Research on Modeling
4	Model Materials	Building Material-Tool Relationship Building Material-Model Relationship
5	Dimension Estimate	Spatial Skills (Visualization, Perception, Rotation)
6	Puzzle	Preparing a Model Plan

As shown in Table 1, a total of six computer-based activities were developed to improve modeling skills. Computer-based activities developed in two cycles. The data obtained under the first and second cycles are presented below.

First Cycle Findings

In the first cycle of the research, first drafts were created. The creation of the draft was started by designing the interface and determining the materials to be included. Figure 3 gives a sketch of the activities in the first cycle.

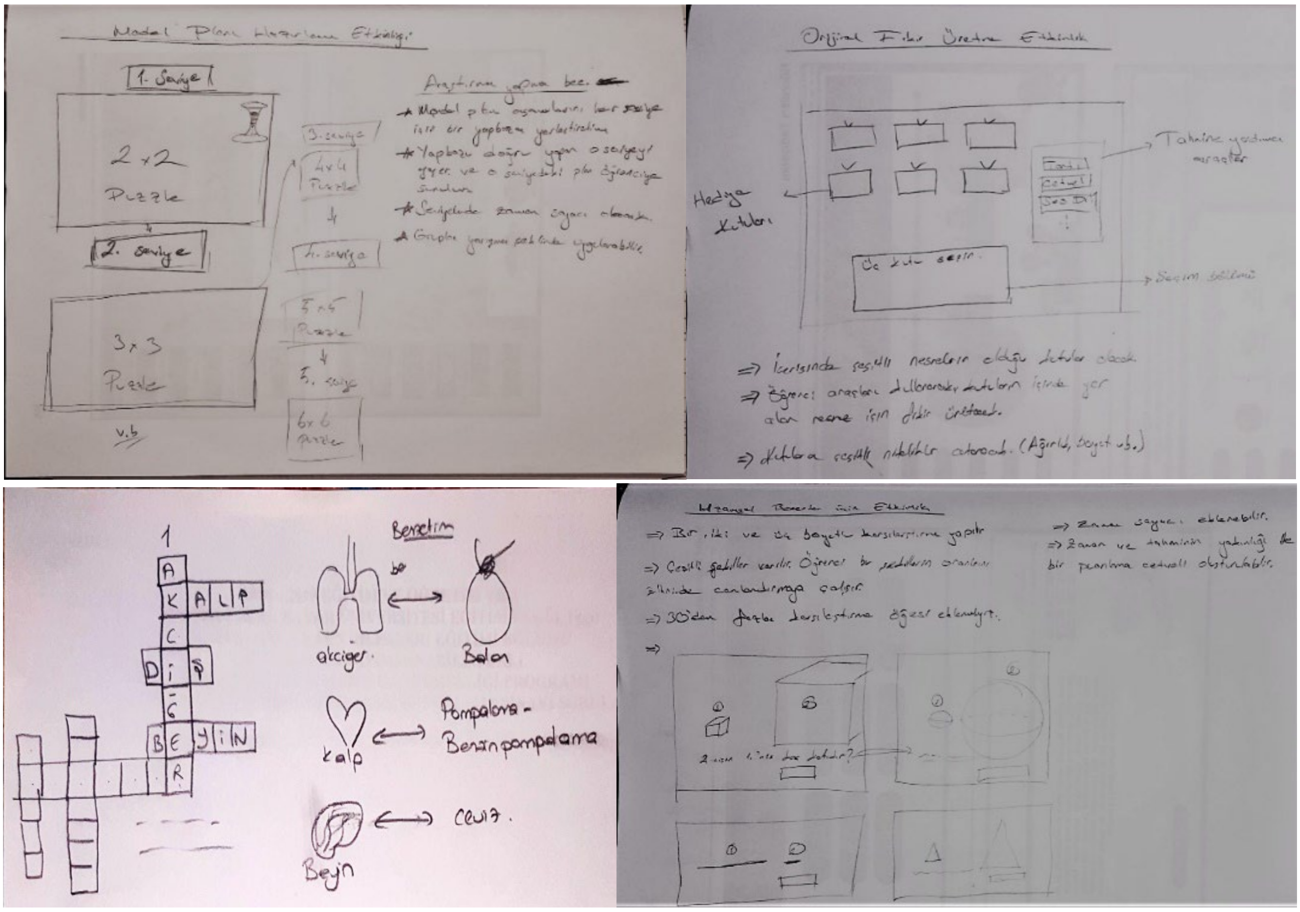

Figure 3. Drafts of activities

It is seen that the first drawing is related to analogical reasoning and making structural relationship skills when Figure 3 is examined. In this sketch drawing, a puzzle is created by simulating the concepts to the tools of daily life. For example (1) the answer to the puzzle of what our basic respiratory organ is the lungs. It was decided that the lungs of the students could be compared to the balloon. Again, the answer to the puzzle of what is our organ that pumps blood to our body is the heart. Here too, the blood pumping of the heart is compared to gasoline pumping of gasoline. Therefore, in the software to be created, it was decided to place these clues in the edges of the puzzle. The second draft in Figure 3 relates to original idea generation. There are three gift boxes and shaking gift boxes, for prediction of the contents of the boxes through their properties. As shown in the drawing, the prediction box will be created, and the students will be asked to make a comparison according to the features in this box. Here the produce an original idea skill is used, which is based on the students' guessing according to the strategy they form. The third draft in Figure 3 is intended to use the ability to conduct research in the cell. Since the organelles in plant and animal cells can be found out because of students' research. The fourth outline drawing in Figure 3 is intended for the properties and where to use the materials and tools. Therefore, it is aimed to develop students' building material-tool relationship and building material-model relationship skills in this drawing. In the fifth activity dimension estimation, the circle, cube and so on. Geometric shapes, one of which is very large and the other two are given very small. The students were asked a question of how many of the small shapes we can combine to achieve the larger shape. The important thing is that the given shapes are both two-dimensional and three-dimensional. Therefore, this draft activity aims to develop students' spatial skills. The last draft in Figure 3 belongs to the puzzle activity. There are 2x2, 3x3 puzzles as shown in this draft. Here the expected behaviour; the first puzzle is given; the student is to explain the first stage of preparing a model plan. When the 3x3 puzzle is made, the second stage of preparing a model plan continues.

The activity development phase has started with field experts and computer experts in the process following the creation of the draft drawings. At this stage, attention was paid to the modeling activities to be animated, the stages in which active-passive buttons will be used and the visual. The steps of transferring the named "Model Materials" activity is explained below:

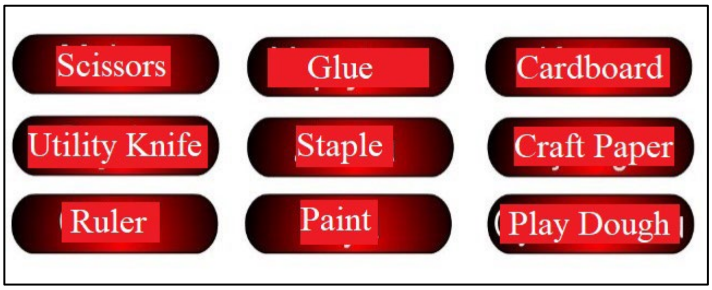

Figure 4. Introduction of the model materials activity

Figure 4 shows the introduction page of the model materials activity. Students can access the information they need to learn about the material or vehicle by clicking on the buttons here. students can access the necessary information for the material or vehicle they want to have information about by clicking on the buttons here. Examples of the content after clicking the buttons are presented in Figure 5 and Figure 6

PAINT
Paint is a type of coating used to color or protect any object. Paint can be applied to any material. It is most used in art, design, industrial coatings, transportation and protection (to prevent contact with water or air). In schools, mostly watercolor, dry paint and pastel paint are used. These are paper, cardboard, etc. These are the types of paints suitable for coloring materials. Special paints should be preferred for fabric or wooden materials. Therefore, when choosing paint, it is necessary to check whether it is compatible with the surface to be painted.

Figure 5. Content of paint button

Scissor
Scissors are tools that are used to cut many materials such as fabric, paper, cloth, hair, and consist of a riveted axis and two blades attached to each other in the middle. There are varieties and forms according to the way they are made or used. Scissors used to cut materials such as tin, thin paper, hair, fabric can be used with one hand, with the help of fingers. On the other hand, with the scissors that gardeners use to cut thin plants such as grass and branches; Scissors for cutting metal sheets, iron and metal wire can be used with both hands.

Figure 6. Content of scissor button

Description of the tools and materials used in the activity as shown in Figure 5 and Figure 6 above. Students reach these contents by clicking the buttons and try to use these skills during the modeling activities after obtaining the necessary information. In this way, the first cycle was completed with the implementation of the activities and the second cycle process, which included the examination of the obtained feedback, correction, and reapplication of the activities, was started.

Second Cycle Findings

The second cycle of the study was started by examining the feedback obtained from the first cycle. Necessary corrections and additions were included in the following process and the activity was reapplied. Completed with the second cycle in the development process of the activities. At the end of the first cycle of the research, some corrections were made regarding the suitability of activities and their correct functioning. The changes in the second cycle process in the activity are explained below. Figure 6 provides the interfaces for the latest state of these activities.

Figure 7. Analogical puzzle and gift prediction activities visuals

Questions of the analogic puzzle were already included in the first cycle. At this stage, the simulations of the answers to the questions asked to the students did not exist visually. For example, the hint of our visual organ appeared as a camera. In the second cycle, the simulations of the clues given to address the student at all levels are expressed visually. In other words, when the student does not know the question in the form of our visual organ and wants a clue, the camera appears on the screen as shown in Figure 6. In the first cycle, "Guess the Gift" activity, the gift packages were different in structure. This made it easier for students to eliminate others when they knew what was in a package. Gift packages were made in the same size and feature to enable students to make more predictions.

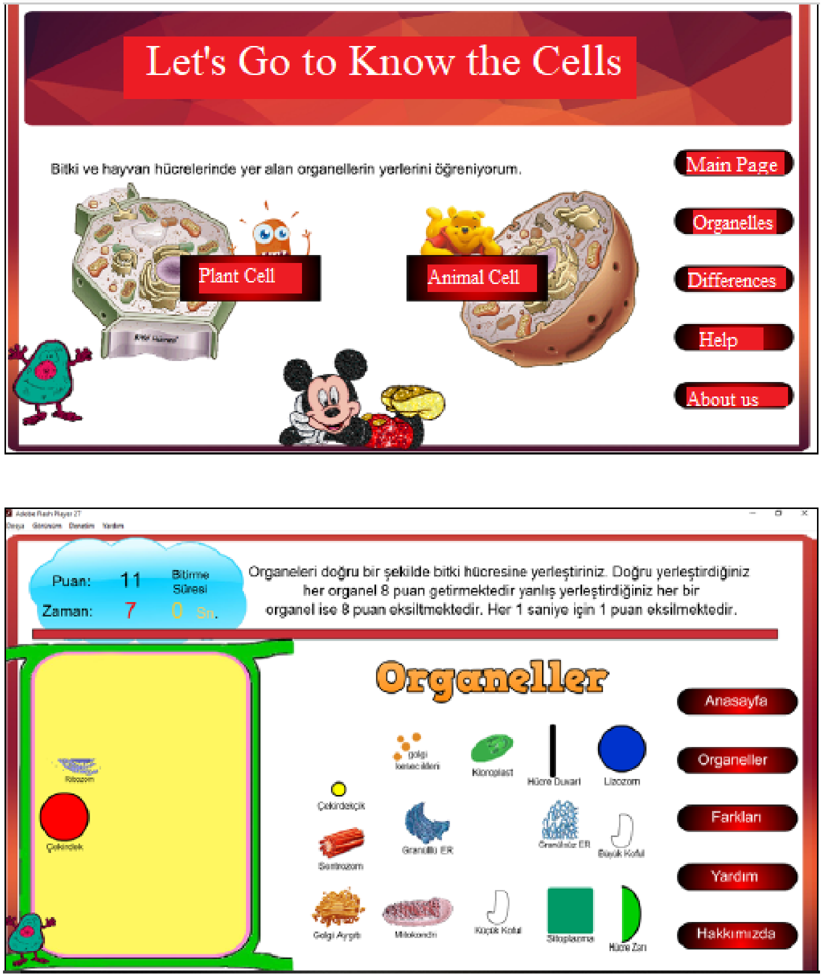

Figure 8. Images of the cell activity

Figure 8 gives an image of the Cell Activity. In the first cycle, all the cell organelles were on the first page. In the second cycle, some active buttons have been added to the first page to make the students understand the subject better and to draw attention to the subject. When there is a comparison of plant and animal cells as shown in Figure 8, it is clicked to the buttons on the first page, when we click the buttons, the organelles appear. In this way, a teaching technique was adopted from simple to difficult.

Figure 9. Content of stapler

Figure 10. Content of glue

Figure 9 and Figure 10 are added a title to the main page of the activity called "Model Materials" and the buttons are placed on the template. In the first cycle, some of the push buttons were found to be incorrect and these errors were correct. In the sections where material and vehicle contents are included, visual improvements are included. These visual enhancements have made the content interactive with the addition of simple animation of tools and materials. Finally, as shown in Figure 9 and Figure 10, a menu is brought to the upper left to provide access to other vehicles. Software errors were corrected in the Dimension Estimate activity. Other than that, no changes were made in content.

Figure 11. Images of puzzle activity

Figure 11 shows the image of the Puzzle activity. The activity shown in this image consists of two stages. The group who completed the puzzles given in the first stage should explain the first step of preparing a model plan skill. If it continues correctly, a second puzzle is displayed that this puzzle is more difficult than the first. When the student completes this, he/she explains the second stage of the preparing a model plan skill. The puzzles given in the first cycle of this activity started more difficult. However, as it is understood from the pilot applications, the student cannot make the puzzle which becomes increasingly difficult. This situation is an obstacle for students to understand the steps of preparing a model plan skill. Therefore, in the second cycle easier puzzles started.

The changes specific to the activities are mentioned above. In addition, in the second cycle, the following corrections were made for all activities:

- Visual improvements are included in the introduction page of the activities.
- Errors in the hitbox of some keys have been corrected.
- The sentences that are not understood in the explanations are corrected.
- More visualization is used.

As a result, after all activities were completed in the second cycle, they were re-applied to the same students. As a result of the implementation, it was decided that the activities were in line with the purpose and that they were working correctly, and the development phase was completed at the end of the second cycle.

DISCUSSION and CONCLUSION

This research was carried out with the aim of planning activities for spatial skills (visualization, perception, rotation), produce an original idea, analogical reasoning and matching structural relationship, building material-tool relationship, building material-model relationship, research on modeling and preparing a model plan skills of middle school students by using design-based research method. The research started with the creation of drafts of the first cycle activity. By examining and correcting the sketches, Flash-based computer activities were developed, and the first cycle was completed by applying to secondary school students. As a result of the examination of the feedback obtained from the first cycle, necessary corrections and additions were made and the second cycle was started. In consequence of the design research process, the second cycle is based on the belief that the activities are fully operational. It has been tried to ensure that the modeling processes of the students are positive through computer-based activities these cycles while using the design research method by conducting. In other words, the activities obtained from this research are thought to contribute to the development of modeling skills of middle school students. The students participate actively in the modeling process through these activities. Because computer-based activities to develop modeling skills have been gave feedback to students directly and giving information about right and wrong, it could be effective in developing skills in a positive way. There are findings that computer-assisted learning environments improve students' modeling skills in the related literature (Barab et al., 2000; Frederiksen et al., 1999; Hung & Lin, 2009; Méheut, 2004; Valanides & Angeli, 2008; Yılmaz, 2012; Yurt, 2011). For example, Yurt (2011) conducted a study investigating the effects of modeling-based activities using virtual environment and concrete objects on students' spatial thinking and mental translation skills. Yurt (2011) designed this study according to one of the experimental research models, pre-test, and post-test control group trial model. In addition, in the experimental groups, the courses conducted by the researcher lasted 9 weeks and a total of 18 different models were developed. As a result of the study, it was stated that developing models using virtual environment improved students 'spatial thinking skills and developing models using concrete objects improved students' spatial thinking skills. Similarly, Yılmaz (2012) has compared the effects of computer-based modeling and physical modeling on the spatial abilities of ninth grade students and their level of comprehension of ionic compounds in their crystal structures. He investigated the effect of computer-based modeling programs and physical modeling on students' level of comprehension. Yılmaz (2012), who was working with ninth grade students, conducted computer-aided modeling programs and modeling practices with play dough in the learning environment. As a result of the study, although there is no difference in the increase in students' conceptual levels in computer aided modeling applications, both types of applications increase their conceptual development and spatial abilities.

Another result obtained from the research is that computer-aided activities will be effective in students' conceptual learning. In other words, computer-based activities to develop modeling skills are effective in concretizing abstract concepts that are difficult to understand in science education. Therefore, the students learn the subjects they do not know and reinforce their knowledge in other subjects, while applying the activities based on modeling skills. A similar result was obtained in the study conducted by Méheut (2004). In his study, Méheut (2004) prepared a two-part learning environment with experimental setups and computer simulations. In this way, he tried to determine the use of mental models of the particle structure of matter to identify and predict physical phenomena. Méheut (2004) stated that the study provided an effective learning environment for understanding the pressure-temperature-volume relationships of gases. This means that experimental mechanisms and computer animations in similar studies contribute positively to the development of students' mental models. Similarly, Frederiksen et al., (1999) study aimed to examine the effect of 10th and 11th grade students' instruction supported by computer simulations on their knowledge level. For this purpose, a total of 32 students attending 10th and 11th classes were divided into experimental and control groups and computer simulations were applied to the experimental group. Both groups engaged in learning activities during the same model. Frederiksen et al. (1999) stated that the experimental group students supported by computer simulations together with learning activities had higher level of knowledge and that they solved the problems with meaningful learning better. This result supports the result of this study. Again, Hung and Lin (2009) carried out the study of developing students' modeling skills by changing the variables related to simple pendulums by using a five-point Likert type scale in experimental design with eighth grade students. As a result of the study, Hung and Lin (2009) stated that computer software contributes teachers to students' understanding of modeling and thinking processes.

In the end of this research, computer aided activities were developed to improve students' modeling skills. It is thought that these computer aided activities will lead to success in model building. In this context, it is suggested that such development studies can be carried out in order to meet the computer-based activities needed within the scope of the FATİH project implemented by the Ministry of National Education. In today's information age, where students are now returning from books to tablets, students' knowledge and skills can be developed more easily and quickly than expected with the help of computer activities to be developed through design research. In this way, rapid development of technology literate individuals needed by countries can improve both education and technological context.

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