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USE OF PEDAGOGICAL ANALOGICAL MODEL IN SCIENCE TEACHING: DNA MODEL WITH CLOTHESPINS[1]

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ABSTRACT

In the present research, the "DNA Model with Clothespins" activity was designed to teach the subjects of nucleotide, DNA, and DNA replication, which are abstract subjects of science. The aim of the research, which was carried out with 20 students in 8th grade, was to examine the effects of the activity on students' achievement on the subject. This paper presents the design, implementation, and evaluation processes of the activity. The pedagogical analogical model, which is a visual analogy tool that simplifies students' complex knowledge and concretizes their abstract knowledge to provide meaningful and long-lasting learning, was used. An achievement test was administered as a pre-test and post-test to evaluate the activity, and students' views were taken about the activity. Data analysis revealed that students' achievement increased in the post-test. Additionally, the students thought that the activity was fun and instructive and enabled them to learn permanently and to understand better.
Keywords: DNA, nucleotide, model, pedagogical analogical model, concretization.

FEN ÖĞRETİMİNDE PEDAGOJİK ANALOJİK MODEL KULLANIMI: MANDALLARLA DNA MODELİ

ÖZ

Araştırmada, fen bilimlerinin soyut konularından olan nükleotid, DNA ve DNA'nın eşlenmesi konularının somutlaştırılarak öğretilmesi amacıyla "Mandallarla DNA Modeli" etkinliği tasarlanmıştır. Ortaokul sekizinci sınıfta öğrenim gören 20 öğrenciyle yürütülen araştırmada etkinliğin tanıtılması ve etkinliğin öğrencilerin konu ile ilgili başarılarına etkisinin incelenmesi amaçlanmıştır. Araştırmada etkinliğin tasarım, uygulama ve değerlendirme süreçleri sunulmuştur. Öğrencilerin kompleks bilgilerini basitleştiren, soyut bilgilerini somutlaştıran, anlamlı ve kalıcı öğrenmeyi sağlayan, görsel benzetme aracı olan pedagojik analojik model kullanılmıştır. Etkinliği değerlendirmek amacıyla başarı testi, ön test ve son test olarak uygulanmış ve etkinlik hakkında öğrenci görüşleri alınmıştır. Veri analizi sonucunda son testte öğrencilerin konu ile ilgili başarılarının arttığı bulgusuna ulaşılmıştır. Ayrıca öğrencilerin etkinliği eğlenceli ve öğretici buldukları, kalıcı öğrenmelerini ve daha iyi anlamalarını sağladığına dair görüş bildirdikleri sonucu elde edilmiştir.
Anahtar kelimeler: DNA, nükleotid, model, pedagojik analojik model, somutlaştırma.

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INTRODUCTION

One of the main goals of education is to prepare individuals for life. The most necessary stage in this preparation is enabling individuals to make sense of the events that take place in daily life. The most effective way to understand these events is by studying science as it is the product of human beings' efforts to access the facts of nature, to explain and predict events, and to understand themselves in this process (Collette & Chiapetta, 1989). Thus, science plays a key role in understanding the realities of daily life since it contains many abstract concepts besides its interconnected subjects. For this reason, science should be taught by making sense of and concretizing science through making connections between subjects. As a matter of fact, Novak (2002) states that meaningful learning can be realized when students make the right connections between the concepts they already have and the new concepts they have acquired.

Recognizing the significance of science in a country's development, countries try to develop curricula to improve science education, create a suitable teaching environment for the implementation of developed curricula, and select the most appropriate method that plays a key role in this process (Ayas, 1995). The material to be used in the chosen methods directly affects the effectiveness of teaching (Çelik, 2017). In science teaching, models are frequently used to make abstract concepts concrete and to explain scientific theories (Düşkün & Ünal, 2015). Models allow students to see from different perspectives and create concrete situations to deal with the fact that science contains many abstract concepts that make it difficult for students to understand (Ayvacı et al., 2015). Scientific models are tools that aim to simplify complex phenomena, concretize the abstract, make the invisible visible, and ultimately allow students to connect new information with prior knowledge (Hestenes, 1996). Models, according to Harrison (2001), are auxiliary materials that help to understand the process of constructing an object, such as microscopes and telescopes, which make visible and understandable what is invisible to the naked eye and act as a bridge from the known to the unknown. Models have a wide range, from chemical formulas and simulations to mathematical equations and maps.

Deoxyribonucleic acid (DNA) forms the basis of the subject of "Genetics" in Biology, a sub-branch of science. A nucleotide consists of phosphate, deoxyribose sugar, and an organic base (adenine, thymine, guanine, or cytosine). Nucleotides combine to form genes and genes combine to form DNA. Chromosomes are formed by wrapping DNA around protein nucleosomes in a spool-like structure (Güneş, 2006). The structure of DNA, the structure of the nucleotide, the nucleotide-gene-DNA-chromosome hierarchy, and DNA self-assembly are all abstract concepts that many students have difficulty understanding. In a 1980 study conducted by Johnstone and Mahmoud, it was reported that genetics was among the biology subjects that students found difficult (Johnstone & Mahmoud, 1980). The situation remained unchanged twenty years later. According to a 1999 study, genetics was at the top of the list of subjects that students found the most difficult (Bahar et al., 1999), and according to a 2001 study, students had difficulties understanding gene and chromosome concepts (Tekkaya et al., 2001). The fact that genetics subjects were categorized as difficult subjects perceived by students was also revealed by studies conducted in the following years (Güneş & Güneş, 2005; Tuncel & Fidan, 2018). Teachers reported that students had difficulty comprehending the subject because genetics was abstract in the study conducted by Kakız (2019), and it was suggested in the same study that genetics should be concretized with concrete examples and activities or taught in a laboratory environment. Genetics, which is an abstract biology subject at the micro level, should be taught using inexpensive, concrete, and visual models, according to Malacinski and Zell (1996). Similarly, in a study conducted by Özdemir (2005), it was discovered that eighth-grade students had many misconceptions about genetics, and it was suggested that the subjects related to genetics be taught in a concrete manner.

Misconceptions about genetics by eighth-grade students generally include confusion about the functions, properties, and shapes of nucleotides, genes, DNA, and chromosomes, confusion about the relationships between

these structures, and errors in mutual organic base pairing in nucleotides (Akyürek & Afacan, 2012; Akyürek & Afacan. 2013; Güney et al., 2007). Recent research in the literature has examined the effect of the 5E model on eighth-grade students' concept learning about genetics (Altınay, 2009), the effect of computer-aided material (Güney et al., 2007), the effect of role-playing and games (Keleş et al., 2006), the effect of conceptual change texts given by analogy in eliminating misconceptions (Akyürek & Afacan 2013), the effect of cooperative learning (Genç & Şahin, 2015), simulation-supported cooperative teaching (Aydoğan, 2019), and graphic materials (Demir & Sezek, 2009) in increasing students' achievement. In similar age groups, the genes and DNA teaching with the analogical model (wool model) was effective in the development of students' conceptual understandings (Venville & Denovan, 2010).

The pedagogical analogical model, which is a visual analogy tool that provides meaningful and long-lasting learning, was used in the current study. The teacher's use of the model as an explanatory model to make unobservable things visible shows its pedagogical structure, while information sharing between the model and the target shows its analogical structure (Güneş et al., 2004). An analogy is a tool used at all levels, from early childhood to Nobel laureates (Richland & Simms, 2015). Bailey (2012) compares analogies to dialects of language used by specific groups, stating that when presenting a new idea or skill, teachers frequently prefer to use analogies of situations that students are familiar with. The use of easily accessible materials from daily life in the model reveals how the current study differs from others. A group of pre-service science teachers developed the analogy of a clothespin for the concept of chromosomes in the study of Dönel-Akgül and Çolak (2021), demonstrating that clothespins can take place in the analogical world of students.

The activity developed in the present study covers the structure of DNA and DNA self-assembly in the "DNA and Genetic Code" section in the eighth-grade for the "Living Things and Life" subject within the Science Curriculum. In the Science Curriculum, there are three related learning outcomes: "Explains the concepts of nucleotide, gene, DNA, and chromosome and establishes a relationship between these concepts", "Shows the structure of DNA on a model" and "Expresses how DNA replicates itself". In the curriculum, it is recommended that these learning outcomes be achieved in 4 class hours (Ministry of National Education [MoNE], 2018).

Many studies have shown that eighth-grade middle school students have various misconceptions about genetics (Akyürek & Afacan, 2012; Akyürek & Afacan. 2013; Güney et al., 2007). Furthermore, this is one of the subjects tested every year in the exam for eighth-grade students transitioning from secondary school to higher education in Türkiye (Kaya & Kara, 2022). The fact that the subject of genetics forms the basis of Biology education subjects at higher education levels reveals the importance of meaningful learning of the subject. Therefore, it is required to teach the subject by concretizing it. It is thought that the "DNA Model with Clothespins" activity developed in the study will enable students to learn the structure and pairing of DNAs by making sense of it through modeling with materials in daily life.

METHODOLOGY

The present study was conducted with a mixed research method in which qualitative and quantitative methods were used together to collect data. Multimethodology is a method in which data are collected, analyzed, and interpreted qualitatively and quantitatively (Leech & Onwuegbuzie, 2009).

The study was conducted using a one-group pre-test/post-test quasi-experimental research design, which does not allow for the randomization of students in the research groups. Due to the implementation of the centralized education system in Türkiye, students in the classes are assigned by the school administration at the beginning of the academic year, and thus the distribution of students to the research group cannot be done randomly, necessitating the use of the quasi-experimental method (Çepni, 2007). The independent variable of the study is teaching with the pedagogical analogical DNA model and the dependent variable is students' achievement in the subject.

PLANNING THE ACTIVITY

The "DNA Model with Clothespins" activity was developed by the researcher. Table 1 lists the source concepts in the pedagogical analogical model as well as the target concepts to which these source concepts are analogized, and which are intended to be taught.

Table 1. Analogical Relationship between Source Concepts and Target Concepts in the Model

Source Concepts	Target Concepts
Pink clothespin	Phosphate
Yellow clothespin	Deoxyribose sugar
Blue, purple, light pink, green clothespins	Adenine-Thymine-Guanin-Cytosine organic bases
Ribbon	DNA strands
Safety pin	Hydrogen bonds
Colored cardboards	Nucleus-cytoplasm

Through six years of experience as a science teacher, the researcher observed the problems that students had with this subject during lessons and observed that students had difficulties in solving the questions on the pairing of DNA. An achievement test was administered to determine students' misconceptions and deficiencies about the structure and self-replication of DNA (Appendix 1). The test, which consists of a total of six questions, five open-ended and one ranking question, was developed by the researcher. The test was reviewed by two field experts and two science teachers. As a result of the review, it was determined that the six-question test provided content validity in accordance with the activity objective and was appropriate for the student level. In the literature, it has frequently been seen that the reliability and validity of tests consisting of open-ended questions have been determined through consulting the opinions of faculty members, field experts, or teachers related to the research topic (Kalkan & Yener, 2022; Taşdemir & Demirbaş, 2010). For the reliability of the test, the percentage of agreement between two independent coders was examined. Eight papers randomly selected from the student papers were evaluated and coded by two science teachers. The percentage of agreement was calculated using Miles and Huberman's (1994) formula [Agreement / (Agreement + Disagreement)]. A consensus percentage of 70% and above between two coders is considered sufficient for reliable coding (Miles & Huberman, 1994), and the consensus percentage for this test was calculated as 92%.

The data obtained from the achievement test were analyzed using the SPSS package program. The test was scored by evaluating the correct answers given by the students to the achievement test questions applied as a pre-test before the activity and post-test after the activity. The first five questions were given 17 points and the last ranking question was given 15 points and evaluated out of 100 points.

In determining the tests to be used in the analysis, the normality of the variables was taken into consideration. This test was chosen because the sample size is a criterion for the normality test to be used and the Shapiro-Wilk test gives the most accurate results in small samples (Ahad et al., 2011). The Shapiro-Wilk test is appropriate when the sample size is between 3 and 50 (Shapiro & Wilk, 1965). In the analysis, a nonparametric test was used because the Shapiro-Wilk value was 0.059 in the pre-test and 0.003 in the post-test ($p < 0.05$). Thus, the Wilcoxon Signed Ranks Test was used in the pre-test, post-test, and achievement-test analysis of the dependent groups.

The data obtained from the test and the researcher's observations and experiences in the past years formed the basis for the development of this activity. The confusion students have between the organic base and nucleotide structures, as well as their inability to make sense of information such as the fact that one of the strands in the replicated DNA is old and the other is new, was planned as issues to be emphasized with the activity. The researcher planned the necessary materials and prepared the activity for this purpose. In order to check the suitability of the prepared activity, the opinions of two field experts and two science teachers were consulted. In response to the feedback, minor changes were made to the activity's content, and the final version was completed. The prepared model was named

"DNA Model with Clothespins". The materials required for the model were planned and provided by the researcher. The activity where the model was put into practice was conducted.

A six-item worksheet was created to guide students throughout the activity. During the activity, students were given a worksheet (Appendix 2) to fill out. At the end of the activity, the achievement test was applied as a post-test. Finally, a questionnaire consisting of three questions (Appendix 3) was applied to reveal the students' general opinions about the activity. Students were asked to answer the questions in the questionnaire in writing. The reliability of the questionnaire was assessed by calculating the percentage of agreement between two independent coders according to Miles and Huberman (1994). Eight questionnaires randomly selected from the answers given by the students were coded by two science teachers. The agreement percentage of the questionnaire was calculated as 88% and it was accepted as a reliable questionnaire.

The data obtained from the questionnaire were evaluated by conducting a descriptive analysis of the answers given to each question in the questionnaire separately. The data in the descriptive analysis were organized according to the themes revealed by the research questions and direct quotations were frequently used to reflect the views of the participants in an eye-catching manner (Yıldırım & Şimşek, 2011). The data obtained from the questionnaire were analyzed in detail and common themes were identified. The frequency of repetition of the codes belonging to the emerging themes was determined, and the data obtained within the framework of the determined themes were tabulated, as well as direct quotations from student opinions.

Materials

The materials included 10 purple clothespins, 10 blue clothespins, 10 light pink clothespins, 10 green clothespins, 43 yellow clothespins, 45 pink clothespins, 50 safety pins, white ribbon, red ribbon, colored cardboards, scissors, and glue. The materials were provided by the teacher.

ACTIVITY IMPLEMENTATION

The research was conducted in a public school with a medium socioeconomic status in Samsun Province. The developed activity was carried out with 20 eighth-grade students. An eighth-grade class was randomly chosen from the school included in the study. The selected class consisted of students with different achievement levels. In four lesson hours, from simple to complex, nucleotide, gene, DNA, and chromosome relationship, DNA structure, and DNA self-replication were explained. In two lessons, the "DNA Model with Clothespins" activity was implemented. The activity was carried out after the subject was covered to ensure a better understanding of the subject and to reinforce it. This activity was implemented after obtaining the necessary permissions from the school directorate.

During the implementation of the activity, five groups of four members were formed. Two rows of students were joined together, and each group was assigned a number. In the dialogs in the research presentation, the teacher was referred to as "T" and the group as "G". The group number is shown as G_1, G_2, G_3, G_4, and G_5. The activity was conducted in groups in cooperation. Each group selected a spokesperson, who answered the questions in accordance with the group's unanimous decisions. During the activity, the worksheet was completed by the group, but the achievement test and the activity opinion questionnaire were answered individually.

In the first stage, the materials to be used and their numbers were written on the board. The teacher managed the activity by guiding the students with questions based on the worksheet. During the activity, time was allowed to answer the questions on the worksheet, and the questions were structured according to the progress:

T: The materials written on the board are on the desk. Given these materials and numbers, how many nucleotides can you make at most?
G_3: 23.
T: Why?
G_3: Since I have to match yellow clothespins and pink clothespins, we can make 43 of them.
T: Any other ideas?

G_2: It's not 43 but 40.
T: Why?
G_2: Each nucleotide must contain phosphate and sugar and each nucleotide must contain a different organic base. Therefore, if we pair equal numbers of colored clothespins Adenine-Thymine, Guanine-Cytosine, there are enough organic bases for 40 nucleotides. …
T: Which material should be substituted for which structure in order to produce the greatest number of nucleotides?
G_5: I choose pink clothespins as phosphate and yellow clothespins as sugar. I choose an equal number of purple, blue, green, and light pink clothespins as the organic base.
T: For which structure will you use the ribbons?
G_2: I'll make strands.
T: Now each group takes the necessary materials from the desk and makes four nucleotides each.

While checking the nucleotide samples made by the groups, it was observed that proper attention was not paid to the phosphate, sugar, and organic base sequences in the structure of the nucleotide. The following questions were asked in this regard:

T: Why did you put the purple clothespin in the center?
G_4: That's because we're using the purple clothespin as Adenine.
T: Isn't adenine an organic base?
G_4: Yes, teacher.
T: So, should the organic base be in the middle of the nucleotide?
G_5: No, teacher, sugar should be in the center, phosphate, and organic base on the edges. So, the purple clothespin should be at the end.
T: Yes, since we are using the purple clothespin in place of the organic base, it should be at the end. Since we will use the yellow clothespin instead of sugar, there should be a yellow clothespin in the middle and a pink clothespin at the other end, which we will use for phosphate. If there are groups that do not follow this rule, please correct them.
…
T: Now let's build a DNA molecule with the nucleotides we made. What do we need for this?
G_1: Strands. So, we need ribbons.
T: Then, from the table, let's cut a ribbon of the appropriate size.

Groups cut ribbons from the main desk. Four groups took only red ribbons from the desk. Therefore, the teacher asked the following:

T: What would you do with these nucleotides?
G_3: DNA.
T: But how many strands does DNA have?
G_3: DNA has two strands.
T: Then you need to take one red and one white ribbon from the desk.

After receiving two different-colored ribbons, each group began to arrange the nucleotides they had formed into DNA strands. At the placement stage, it was observed that some groups made the organic base pairing incorrectly.

T: Do we pay attention to organic base pairing in opposite strands of DNA?
G_1: But we don't have Guanin.
T: What are you going to do, Guanin?
G_1: To put it opposite cytosine.
T: You're going to put it opposite cytosine? Or opposite the cytosine nucleotide?
G_1: Opposite the cytosine nucleotide.
T: Good. So, we don't confuse a nucleotide with the organic base. The nucleotide is named according to which organic base is present in the nucleotide. Organic bases alone cannot be placed in DNA. However, they are organized as nucleotides. So now each group completes the nucleotide they need by taking it from each other.

After the necessary strands were completed, the bonding between the nucleotides started.

T: We move on to building bonds between nucleotides. With what material will we build this bond?
G5: With safety pins.
T: Correct. Now, insert a safety pin between the two nucleotides to form the bonds (Since the eighth-grade curriculum does not include the details of double hydrogen bonds between Adenine and Thymine nucleotides and triple hydrogen bonds between Guanine and Cytosine nucleotides, a single safety pin is used to represent the bonds).

The next step was to insert the DNA into the cell. For this purpose, the teacher gave the following instructions.

T: Where is DNA located?
G_3: In our body, teacher.
T: Where in our body?
G_5: In our cell.
T: Where in our cell?
G_5: In the core.
T: So, let's make a cell into which we can insert the DNA we have created. Let's make the cell and its nucleus using cardboard. Let's make the cytoplasm and nucleus of the cell in different colors.

It was observed that students were undecided about cutting the cardboard while forming the cells. The students were then first asked which type of cell they would like to make. Four of the groups answered animal cells. They were reminded of the seventh-grade topic of cell shapes and were instructed to make them round. The first group stated that they intended to use the angular yellow teacher's desk as a plant cell, with a purple seed in the center. Students were permitted to use the teacher's desk if its size and shape were appropriate. After the cells were arranged, the prepared DNAs were inserted into the nucleus of the cell by all groups. Then the groups proceeded to the DNA replication stage. The image of the students' work on creating the cell and its nucleus is given in Photograph 1.

Photograph 1. Groups Works on Creating Cell and Nucleus

T: What do you need for cell pairing?
G_2: We need more nucleotides.
T: Then each group should prepare the nucleotides they need.

After the nucleotides were prepared, the direct pairing was observed in some groups. The teacher then provided some guidance.

T: Where does DNA replication take place?
G_2: In the core.
T: Where will the nucleotides that come to the nucleus to replicate be located?
G_3: In the cytoplasm, teacher.
T: Correct. So, let's place our nucleotides to be replicated in the cytoplasm.

After the DNA molecule to be replicated was placed in the nucleus and the nucleotides to be used in replication were placed in the cytoplasm, the replication phase started. Photograph 2 shows the model before the replication phase.

Photograph 2. The DNA Molecule Before Replication and the Location of Nucleotides in the Cell

T: What is the first step of replication?
G_5: From one end, the DNA will be opened like a zipper, and the appropriate nucleotides will emerge from the cytoplasm and settle in the opposite end.
T: What do you mean by appropriate nucleotides?
G_5: For example, the nucleotide Adenine will be replicated with the nucleotide Thymine and the nucleotide Guanin will be replicated with the nucleotide Cytosine. That is, the purple clothespin will be opposite the blue clothespin, and the light pink clothespin will be opposite the green clothespin.
T: Yes, let's complete the DNA replication as your friend told us.

It was observed that the groups made the replication correctly at this stage. The groups first started the DNA strand from one end and inserted the appropriate nucleotides in the new strand and then continued the unfolding to the other end. Two identical DNAs obtained as a result of replication are given in Photograph 3.

Photograph 3. Two DNA Molecules Resulting from Replication

T: What do we see? What are the events that occur as a result of replication? Let's get one answer from each group.
G_1: Two DNAs were formed.
T: Are these DNAs similar?
G_2: They are identical.
G_3: The nucleotides to be replicated were waiting in the cytoplasm.
G_4: The number of nucleotides in the nucleus increased; the number of nucleotides in the cytoplasm decreased.
T: Are the strands in the resulting DNA old or new?
G_5: In every DNA there is an old and a new strand.

The teacher then made the following remarks.
T: Your friend is right. In each DNA that is formed as a result of replication, there is a new and an old strand. Do we understand why the questions say that the old strands act as molds or that the DNA inherited the old strands from its ancestor?
G_1, G_2, G_3, G_4, G_5: Yes, teacher.

EVALUATION OF THE ACTIVITY

Evaluation of the Achievement Test

When the answers given by the students to the achievement test were evaluated, the arithmetic mean was calculated as 45.75 for the pre-test and 83.85 for the post-test. In the achievement test, the students' scores from the pre-test and post-test were analyzed with the Wilcoxon Signed Rank Test. The results obtained are presented in Table 2.

Table 2. Wilcoxon Signed Rank Test Results for Pre-test and Post-test Scores

Post-test/Pre-test	N	Mean Rank	Sum of Ranks	Z	p
Negative ranks	0	0.00	0.00		
Positive ranks	18	9.50	171.00	-3.739	**0.000***
Ties	20				

**: $p < 0.05$*

It was found that there was a significant difference between the pre-test and post-test scores of the students for the achievement test [$z = -3.739$, $p < 0.05$]. The students' positive mean ranks (9.50) were higher than their negative mean ranks (0.00), indicating that the significant difference was in favor of the positive ranks. So, it shows that the significant difference was in favor of the post-test. This result shows that the activity increased students' achievement on the structure and DNA replication**.**

Evaluation of the Activity Opinion Questionnaire

At the end of the activity, the students were asked for their opinions about the "DNA Model with Clothespins" activity through a questionnaire. The analysis of the students' answers to the question about their thoughts on the activity in the questionnaire is given in Table 3.

Table 3. Students' Views on the Activity

Themes	Codes	Response Frequency
Cognitive Views	Instructive	12
	Better understanding	18
	Permanent learning	5
Sensation Views	Fun/enjoyable/ nice	45

When the students' perspectives on the activity were examined, it was discovered that they held cognitive views that the activity was instructive, providing a better understanding and permanent learning. Furthermore, it was discovered that the students had sensation views in which they rated the activity as fun, enjoyable, and nice.

It was notable that the majority of the students expressed their thoughts by referring to the clothespins. One student expressed his opinion on this issue as follows: "I liked learning the subject with clothespins used in daily life, I had a lot of fun". It is thought that the use of materials used in daily life as learning materials in lessons attracts students' interest.

The second question asked whether the activity was effective in teaching the structure and replication of DNA. This question was answered positively by all of the students.

The next question asked students what they learned as a result of participating in the activity. The answers of the students about what they learned that they did not know before due to completing the activity are given in Table 4.

Table 4. Students' Responses on What They Learned Through the Activity

Themes	Codes	Response Frequency
Structure of DNA	The organic bases in the nucleotides in the opposite strands of DNA that bind to each other	17
	DNA has two strands	6
Organic base-Nucleotide-DNA relationship	Nucleotide and organic base are not the same structure	11
	Organic base in the structure of the nucleotide	10
	Each nucleotide contains phosphate and sugar	8
DNA replication	The DNAs that are replicated are the ones where one strand is old and the other is new.	19
	When DNA is replicated, two identical DNAs are formed	17
	The nucleotides used for replication come from the cytoplasm	15

The responses to what the students learned from the activity that they did not know before were categorized into three themes. In the theme of the structure of DNA, six students stated that they learned that DNA is double-stranded, and 17 stated that they learned that bonds are formed between the organic bases in the nucleotides in opposite strands. Under the theme of organic base-nucleotide-DNA relationship, 11 students stated that nucleotide and organic base are not the same, 10 stated that there is an organic base in the structure of nucleotide and eight students stated that each nucleotide contains sugar and phosphate. In the theme of DNA replication, 19 students stated that in each of the replicated DNAs, one strand was old and the other was new, 17 stated that the DNAs formed as a result of replication were identical, and 15 stated that they learned that the nucleotides to be replicated came from the cytoplasm.

CONCLUSION and SUGGESTIONS

In the present study, a model with materials used in daily life was designed to teach the hierarchical relationship between organic base, nucleotide, and DNA, the structure of DNA, and DNA replication. The students assisted in the gradual transformation of the materials into

models and the application of the replication. It was concluded that the students' knowledge of the subject increased based on the results of the achievement test administered before the activity as a pre-test and after the activity as a post-test. As a result of the statistical evaluations, it was concluded that a significant difference emerged in favor of the post-test compared to the pre-test. The details of what students stated they learned under the themes of organic base-nucleotide-DNA relationship, DNA structure, and DNA replication in the questionnaire in which students were asked for their opinions about the activities support this result. These results show that the "DNA Model with Clothespins" activity increased students' achievement in the subject. Furthermore, these results are consistent with those of Akyürek and Afacan (2013), who discovered that analogies improved students' understanding of concepts related to the subject in their study in which the subject of heredity was taught by analogy.

Students expressed that the activity helped them understand the subject better and that they found it instructive. It was concluded that the majority of the students found the activity fun. It was also observed that the students had a lot of fun during the implementation. This finding is consistent with Yılmaz and Ünal's (2020) suggestion that pedagogical analogical models be used more in science teaching to increase students' interest and motivation in light of the data obtained in their study.

The fact that the majority of students mentioned the use of clothespins in the activity demonstrates that the realization of learning with easily accessible material in daily life piqued their interest. Although several studies have shown that genetics subjects are generally perceived as difficult by students (Güneş & Güneş, 2005; Tekkaya et al., 2001; Tuncel & Fidan, 2018), Subaşı (2020) concluded that gifted students tend to perceive biology subjects as easier. This ease has been attributed to their ability to relate biology subjects more readily to daily life. Therefore, it can be said that the use of clothespins, a material used in daily life, in the activity carried out within the scope of the study facilitated students' understanding.

According to the findings of the study, the activity used to teach the hierarchical relationship between organic bases, nucleotides, and DNA, the structure of DNA, and DNA replication provided students with both cognitive and affective development. It was observed that the activity encouraged students to think, and the pedagogical analogical DNA model used within the scope of the activity increased students' conceptual understanding by concretizing abstract subjects.

The materials used in this study's model were designed by the researcher. In future research, the selection of the materials used can be left to the students. Allowing students to choose the materials they will use enables them to develop their imagination and creativity.

Pedagogical analogical models should not be limited to DNA but should be developed and applied to other abstract science subjects as well, as they will help students learn by making sense. Furthermore, extending the activity developed for eighth graders in middle school to secondary school students will allow them to better understand the subject and build a more solid foundation in genetics.

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Appendix 1

Achievement Test

1. What are the structures that create the nucleotide?

2. How many types of nucleotides are there?

3. What are the structures which create DNA?

4. How is the structure of DNA?

5. Why does DNA replicate itself?

6. Line up the DNA's self-replication steps.

( ) Oppositely located nucleotides recombine. Thus, a new thread begins to form.

( ) Nucleotides complete the opposite strand of the separated DNA strand.

( ) The DNA opens like a zipper and the DNA strand begins to unravel.

( ) The opening which started from one end goes until the other end and nucleotides located. Thus, two identical DNAs are formed and replicate. One strand of each DNA formed is old and one strand is new.

Appendix 2

Worksheet

1. Write the names of the materials given to you and create a nucleotide below.

2. How many nucleotides can you create the most?

3. Which material will you use instead of which structure?

4. Create a DNA molecule with the nucleotides you created.

5. Where will you position the DNA in the cell?

6. Where do nucleotides which will be matched take place?

Appendix 3

Activity Opinion Questionnaire

1. What do you think about the “DNA Model with Clothespins” activity you completed?

2. Was the activity helpful in learning about the structure and replication of DNA?

3. What did you learn because of engaging in this activity that you did not know before?