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Abstract
The purpose of this study is to carry out sample classroom applications in the teaching of the molecular structure of deoxyribonucleic acid (DNA), which is the basis of the field of molecular biology, and obtaining the opinions of teacher candidates on these applications after they are completed. This is a basic, qualitative research study. The study was conducted in the fall semester of the academic year 2021-2022 at the Faculty of Education of a state university in Ankara. The participants from whom the data were collected were determined by the convenience sampling method. The research study group consisted of 15 teacher candidates, who were third-year biology students taking the molecular biology course. The interview form, developed by the researchers themselves and containing three questions, was the data collection tool for the study. Classroom applications used for the purposes of the study span a seven-year period. Teachings and other activities throughout the process were explained in detail. Thematic analysis, one of the qualitative analysis techniques, was used to analyze the data. In this study, an exemplary teaching practice/method was developed in DNA teaching. The findings showed that teacher candidates who took part in the application had positive views about the teaching of the subject and the process. In the future, various other teaching practices for other abstract concepts in biology can be developed and the views of prospective teachers explored. The effects of these classroom practices on the academic achievements, attitudes and motivation etc. of teacher candidates can be examined.

Keywords: DNA, DNA Teaching, Biology Teacher Candidate, Classroom Application

INTRODUCTION

Nature is a living phenomenon in which a macro universe, perceivable with a naked eye, and a micro universe, observable only with technological tools, are systemically integrated. Curios to discover the unknowns of the universe, humankind explores this phenomenon in every way to unlock the secrets about life, which is particularly the case with molecular structures not perceivable at a macro level. One of the greatest discoveries made recently unlocking the genetic code of life, was undoubtedly the discovery of deoxyribonucleic acid, abbreviated as DNA. Although DNA was known to humans, it was not until the middle of the 20th century that there was enough information about its structure. For this reason, many experiments have been carried out to decipher the molecular structure of DNA (Langridge et.al., 1960; Pauling & Corey, 1953, Watson & Crick, 1953; Zamenhorf, Brawerman, & Chargaff, 1952). In the process, different models have been proposed depending on experiments conducted by different scientists. The best known of these models is the "Double Helix DNA Model", which was introduced in 1953 by James D. Watson and Francis H. C. Crick, designed in three dimensions. This model was used to explain the molecular structure of deoxyribonucleic acid on the basis of available information (Watson & Crick, 1953). The specific sequence of 5-carbon sugars (deoxyribose), nitrogenous organic bases (purine-pyrimidine), and phosphate molecules in the DNA structure were elucidated. This helped life sciences such as biochemistry and molecular genetics thrive, paving the way for new developments on the back of ground-breaking research. Today, much more is known about DNA, and the science of life is built on this very basic information.

LITERATURE REVIEW

DNA, which contains the genetic information of life, has a fine structure that can be delineated by nano metric measurements. For this reason, a concrete examination with today's imaging techniques is not possible. Structures that cannot be studied in concrete terms inevitably lead to difficulties understanding their essence or other misconceptions. Therefore, understanding DNA, the most fundamental subject in biology, more specifically genetics and molecular biology, can present some challenges for students (Bahar, Johnstone, &

Hansell, 1999). Challenges around building concrete images of the concept in one's mind, and alternative concepts, are major challenges for students and teachers (Tibell & Rundgren, 2010). Initially, both teacher and student groups highlighted the DNA structure and its properties as difficult concepts in genetics (Gungor & Ozkan, 2017; Nopparatjamjomras, 2012).

Students at different levels of education; from elementary school to university, may have misconceptions due to difficulties with understanding the DNA structure and its properties. For example, in a study conducted with eighth grade students, students' misconceptions about genetics were examined, and they were found to have incomplete information or misconceptions about basic concepts such as gene, DNA, and chromosome (Koc & Turan, 2018; Tatar & Koray, 2005). In studies examining high school students' understanding of the concept of the gene (Zengin, 2019) and mitosis-meiosis (Atilboz, 2004), it was found that they had misconceptions about DNA. In addition, a study examining science teacher candidates' views on the concepts of genetics, showed that they had misconceptions about the concepts of gene, DNA, and chromosomes (Saka & Cerah, 2004). The reasons behind these misconceptions are teachers' insufficient knowledge of the subject, students' insufficient prior knowledge and inaccurate biases, and teacher-centered and rote learning (Tekkaya, Capa, & Yilmaz, 2000).

To address the misconceptions students have related to these concepts, to provide better understanding or help make abstract concepts more concrete, various teaching practices are carried out and recommendations are made. For example, Altinay's (2009) research examined the effect of the 5E model-based teaching method on eighth grade elementary students' learning of genetic, DNA, gene, and chromosome concepts and found that 5E model-based teaching improves student learning of genetics and helps to eliminate misconceptions about these concepts. Keles, Usak and Aydogdu (2006) found that student-centered teaching practices (role-playing and games) improved student success when teaching the DNA-Watson-Crick model to eighth grade elementary school students. Altun, Celik and Elcin (2011) showed that conducting experiments on DNA isolation and electrophoresis techniques to teach molecular biology, biotechnology, and genetic engineering in a lasting and meaningful way to high school students, deliver much better results than other methods.

In addition to students, there are other studies intended for teacher candidates and university students employing different techniques/applications. Akgül and Colak (2021) evaluated the analogies formed by science teacher candidates for the concepts of genes, DNA, and chromosomes, considering their structures and types. Accordingly, it was found that teacher candidates formed various analogies around DNA, and it was assumed that understanding of concepts could be improved by developing analogies in the classroom. Yurdatapan and Sahin (2013) investigated the effects of creating models and using animations on teaching the concepts of DNA, RNA, DNA replication, and protein synthesis to science teachers' candidates and they found that using animations is more effective in reinforcing learning. In his study with science teacher candidates, Sahin (2018) identified the misconceptions about DNA replication and protein synthesis and attempted to address these using various techniques. Howell, Van Dijk, Booth, Helikar, Couch and Roston (2018) provided an example of delivering a 3D model-based course on DNA supercoiling in a biochemistry class, best practices for designing and printing 3D Models. Students reported that physical models facilitated the learning of abstract subjects. In another study by the same team (Howell, Booth, Sikich, Helikar, Roston, Couch, & Van Dijk, 2019), three interactive learning modules with dynamic 3D models to help biochemistry students visualize bio molecular structures and eliminate their misconceptions about DNA and RNA structures and functions were used. It was observed that students responded positively to these modules and their learning outcomes were realized to a great extent. In addition, Yılmaz, Karakoc-Topal, and Oz Aydin (2021) designed WEB 2.0 tools for teaching DNA to biology teaching students and an experiment on DNA and asked teacher candidates their opinions. Altiparmak and Nakiboglu-Tezer (2009) conducted an experimental study with biology teacher candidates to understand the basic concepts of molecular biology such as DNA, central dogma, and DNA manipulation. As group work, students were told to form groups for paper model-making and it was found that the paper model group was more successful.

As can be seen, various misconceptions or learning difficulties can arise when teaching DNA and other molecular structures. To overcome these difficulties, many innovative classroom applications were tried. Visualization and concretization are particularly important, especially to overcome difficulties with learning. Visualizations play a crucial role as conceptual tools in teaching and research, changing the way we think about phenomena in molecular biosciences (Tibell & Rundgren, 2010). It is considered important to develop concrete materials for correct and permanent learning of DNA and related concepts (Saka & Cerrah, 2004). Each new application to help concretize abstract topics serves as a crucial contribution to learning the properties and molecular structure of DNA and sheds light on new findings. As referenced in studies mentioned above, activities and practices such as developing different lesson modules, viewing animations, developing paper models, 3D model based lessons, developing analogies, using WEB 2.0 tools, and experimenting helped learners visualize DNA and contributed to lesson designs. It is critical that candidate teachers learn these subjects accurately, and effectively and teach them to their students in the same way. Therefore, innovations in teaching the difficult-to-learn molecular structure of DNA are always needed. Because there is a need to better understand the difficulties of learning science to eliminate misconceptions about scientific concepts, and to make radical changes to the teaching-learning process in order to promote meaningful learning (Gil-Perez & Carrascosa, 1990). Within the scope of this research, a unique application process was carried out in the teaching of the molecular structure of DNA, which included activities such as reading activities, 3D model design and homework. Reading enables people to direct their behaviours, enrich their inner world, and broaden their perspective (Koc & Müftüoglu, 2008). Along with these benefits of reading, students can develop their own mental models about scientific concepts (Treagust, Chittleborough, & Mamiala, 2002) and simplify complex phenomena (Justi & Gilbert, 2002) with 3D modelling. Finally, it is easy to transfer what is learned to real life with home works, which is a common practice and teaching strategy used by teachers all over the world for years (Forster, 2000). Building on this, the current study seeks to try and test a new teaching method with biology teacher candidates in a classroom environment and to get their opinions about the process.

METHODOLOGY

Research design

The purpose of this study, a basic qualitative research study, is to carry out sample classroom applications in the teaching of the molecular structure of deoxyribonucleic acid (DNA), which is the basis of the field of molecular biology, and obtaining the opinions of teacher candidates on these applications after they are completed. A research study designed on this basis seeks to understand the meaning of a phenomenon from the onlookers' perspective and is concerned with how people interpret their experiences, how they construct their worlds, and what meaning they assign to their experiences (Merriam 2009). Under the study, student-centered activities and teaching applications were applied in the classroom for teaching DNA. Afterwards, teacher candidates' opinions were asked about their classroom experiences. In this way, it was demonstrated how teacher candidates made sense of the practices and activities related to the teaching of DNA.

One of the researchers is an expert in molecular biology and is the lecturer responsible for teaching this course. Other researchers are faculty members who are experts in science education and biology teaching. Therefore, it can be argued that researchers are capable of conducting instructional activities, gathering data, and executing analysis processes in accordance with their areas of expertise.

Study group

The participants from whom the data were collected were determined by the convenience sampling method (Cohen, Manion, & Morrison, 2007). With convenient sampling, researchers select volunteering participants who are easy to reach, and suitable for the research (Gravetter & Forzano, 2012), to gather data. Therefore, for the current study, the researchers enrolled students in the molecular biology program, because they were easily accessible. As a result, the research study group consisted of 15 teacher candidates who were third-year students of a state university in Ankara taking the molecular biology course in the fall semester of 2021-2022. The ages of the participants range from 19 to 21 and one of the prospective teachers is male and 14 of them are female.

Application process

This study spans a timeframe of six weeks and below are the subjects taught, and other activities that will be conducted throughout the process. With six-week application process, it is aimed to learning the genetic materials, the structure of DNA and nucleic acids, DNA replication and recombination, and the layout of the hereditary molecule. In the 7th week, the in-class evaluation of the activities and the application of the semi-structured interview questionnaire consisting of three questions took place. The work plan for the implementation process is given in Table 1.

Table 1:Work plan for the implementation process

Time (Week)	Work plan
1	Giving information about the course and forming groups, introduction to the subject
2	Explaining the structure of DNA and experiments on DNA being genetic material. Homework: Double helix: Giving the reading of the book The story of DNA structure decoding (Watson, 2013) as homework
3	Teaching the structure of nucleic acids Homework: The properties of the Watson-Crick model and its drawing as an open molecule
4	Classroom activity: Making of DNA molecule with puzzle at a molecular level
5	Teaching DNA replication and recombination Homework: Individual drawing of the DNA model and replication in eukaryotes and studying the DNA model in groups of two
6	Arrangement of the hereditary molecule in organisms

	Homework: Asking students to draw the structure of the hereditary molecule in eukaryotes, as individual work
7	In-class assessment of activities as homework in the 5th and 6th weeks Application of the semi-structured interview form

1st week: At the beginning of the course, information was given about the class schedule, the instructor's notes, and reference works.
The study program of the students was set in 3 levels as indicated below.
(1) Individual works of students: They were asked to keep a notebook and make drawings on the topic in their notebooks, based on their course books which they were given to use as reference material during the teaching of the lessons. In addition, they were asked to do research on assignments and write them down in their notebooks. Examples of individual assignments prepared by students were given (Figure 1).
(2) Forming groups of two: The students were divided into 7 groups, as 6 groups of 2 people and 1 group of 3 people. These groups were asked to prepare their assignments in the form of 3D materials. Examples of models that students made as group work during extracurricular hours were given (Figure 2).
(3) Making groups for classroom activities: In order to make the DNA molecule at a molecular level, the class was divided into 2 groups of 7 and 8. Examples of classroom work done by the students, who were divided into two groups, are given in Figure 3.
The second class session was dedicated to teaching the history of molecular biology-genetics. Starting from the pan-genesis theory proposed by Aristotle in 384-388 BC, developments in biology at the molecular level throughout the ages were discussed.
2nd Week: Experiments on the structure of DNA and its property as genetic material were explained. After telling students that genetic material has the ability to self-replicate, store information, express that information, and diversify through mutation, the Grifith transformation and Hershey-Chase T2 bacteriophage and transfection experiment, and direct and indirect evidence that DNA is genetic material in eukaryotes was explained with evidence. Experimental studies where genetic material in some viruses is RNA, were also taught.
Homework: The book 'Double Helix: The story of DNA structure decoding' by James D. Watson (2013), was given to students as homework, to read and write a summary of, and student work was discussed for 15 minutes in the following session. Students read James D. Watson's book describing the structure of the DNA helix and explaining the events that led him and Francis Crick to make this discovery, analysing book in a way that would make them make sense of the emotions that arose in the process of achieving success, such as competition, ambition, and anxiety, along with the scientific process itself. This book, which describes the creation of the model, its publication in Nature magazine in 1953, and the awarding of the Nobel Prize in 1962, was found by students as inspirational.
3rd Week: The building blocks of nucleic acids and the Watson-Crick model were described. The chemical structure of nucleic acids and their building blocks, nucleotides, were mentioned. Purine and pyrimidine nitrogenous bases, the biochemical structures of deoxyribose and ribose pentose sugar and phosphate groups, and the chemical bonds between them, were studied in detail. In addition, chemical bonds formed by biochemical structures and phosphodiester, hydrogen and glyosidic bonds were drawn on the board.
Mononucleotide, nucleoside diphosphate, nucleoside triphosphate images were projected onto the wall to help students gain familiarity with these molecules.
Homework: The properties of the Watson-Crick model and its drawing as an open molecule were given as individual assignment. In addition, the groups were asked to reproduce the DNA molecule as a 3D material. In this study, students were allowed to get creative and design a DNA molecule using readily available materials. The things to consider when designing a DNA molecule were determined.
4th Week: The class was divided into two groups and students were told that the materials they created, their drawings, notes, use of books, and the internet were free. These two groups were given red, orange, blue, black and white coloured beads representing the hydrogen-carbon-nitrogen-oxygen atom, with small holes connecting them to each other. Although each atom has a different colour, the information about what colour symbolizes what atom was not shared with the students, but the information that they should make a connection between the number of bonds made by the atoms and the number of holes on the beads was shared. After determining what bead represents what colour, the students started to create a DNA model at the molecular level. After the completion of the task, the groups were allowed to discuss with each other how the DNA helix was prepared at the molecular level.
5th Week: DNA replication and recombination was covered considering the following topics. Experiments supporting the DNA fragmented, hidden and semi-hidden model were included. These experiments are the semi-hidden model experiments performed by Meselson and Stahl in Bacteria and Prokaryotes and on the root tips of beans and eukaryotes by Taylor, Woods and Hugles. After giving information about DNA polymerase enzymes and mechanisms in prokaryotes, the more complex mechanism of replication, and enzymes managing the synthesis process in eukaryotes, were discussed. By asking questions to the students, the elimination of

telomere shortening, that occurs at the end of replication of the ends of linear chromosomes, by a unique enzyme containing RNA was discussed.

Homework: Students were asked to draw the DNA model and replication in eukaryotes, as individual work. In addition, the previously determined groups were given a take-home assignment to make 3D models of DNA model and replication in eukaryotes, outside of class hours.

6th Week: Students were asked to do brainstorming about how the hereditary molecule could be placed considering viroids-virusoids viruses - prokaryotes and eukaryotes, and then the subject was covered in detail. With eukaryotes, the structural arrangement of the hereditary molecule in the nucleus, mitochondria and chloroplasts, the basic packaging units of chromatin, the nucleosome, and upper layers, the solenoids, and finally the chromosomes and their structures were also covered.

Homework: The students were asked to draw the nucleosome and solenoid of eukaryotic DNA, chromosomes, and the classification of chromosomes in their notebooks. In this way, it was ensured that they had a more concrete picture of the subject of how the 3 billion base long DNA molecule, with reference to humans, is packed tightly into the nucleus of a cell, which is a highly abstract and elusive issue.

7th Week: As homework, students made assessments of activities in the classroom on week 5 and 6 whereby the groups explained the model they prepared, while other students shared their thoughts on the model. Afterwards, the semi-structured interview form consisting of three researcher-developed questions was applied.

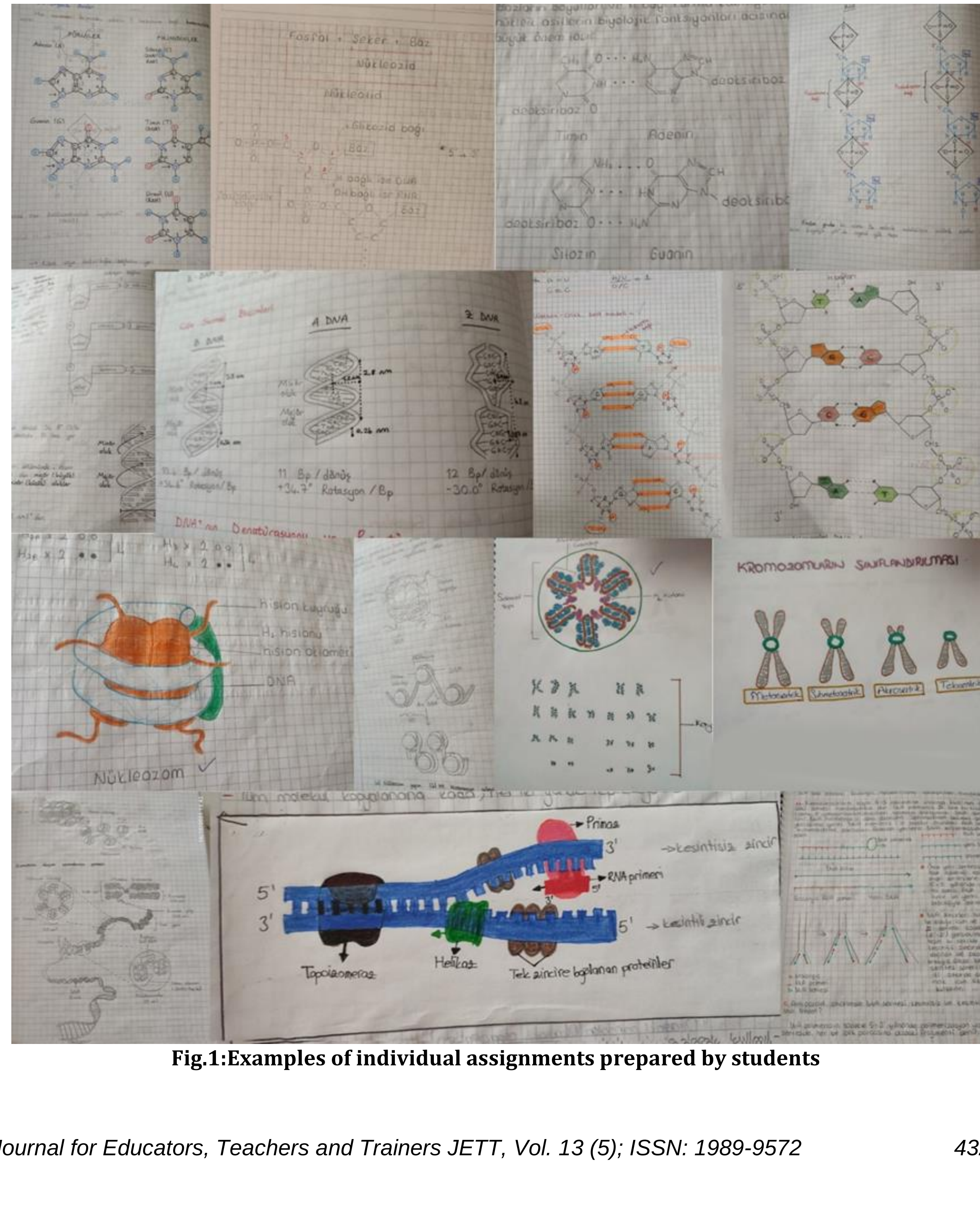

Fig.1:Examples of individual assignments prepared by students

Figure 2:Examples of models that students made as group work during extracurricular hours

Figure 3: Classroom work done by the students in groups of two

Data collection tool

The data collection instrument used was a form that contained semi-structured interview questions prepared by the researchers to obtain teacher candidates' opinions about the teaching process in the classroom. First of all, an interview form consisting of 6 questions was prepared by the researchers. Then, the questions were presented to four faculty members experts in science education and biology education, and necessary amendments were made in line with the feedback received. Based on feedback from the experts, some questions were changed because they were not understandable, and it was decided to remove some of the questions since they did not fit the scope of the research. As a result of the arrangements made, 3 questions remained in the semi-structured interview form. With this form, data were collected on the seventh week when the teaching activities ended. These questions were:

(1) What are your thoughts on the teaching process of the related subject (DNA)?
(2) Have there been any changes to your learning areas during the teaching of the subject? How?
(3) When you think about the process, what stage do you think contributed the most to you? Why?

All data obtained from the interviews were converted into written text in a computer environment, after obtaining the consent of the participants. Since the teacher candidates' own sentences are given directly in the results, each teacher candidate was given code names such as T1, T2, T3....

Data analysis

Various steps are suggested for the analysis of qualitative data (Braun & Clarke 2006; Cresswell 2013; Robson & McCartan 2016). Accordingly, a five-stage thematic analysis method was used in the analysis of qualitative data obtained through open-ended questions (Braun & Clarke 2006): recognizing data, creating initial codes, searching for themes, reviewing themes, identifying and naming themes. First of all, the answers to the open-ended questions were written down and the organized data set was internalized via repeated readings. Initial codings were done during repeated readings. Themes were created according to the codings and the notes taken. The codes were grouped under different themes according to their relevance. Then, all data were reviewed and the suitability of the classification was checked. After the theme-code compatibility was achieved, the frequencies were calculated and thus the qualitative data were converted into quantitative data (Boyatzis, 1998). The reliability of the codes was determined by calculating the inter-coder agreement. According to Yildirim and Simsek (2013), this rate should be over 70% and Miles and Huberman (1994) think it should be over 80%. The analyzes from the current study showed that the rate of coherence between the three science educators expert coders was 82% and it was decided that the codes were consistent. In order to facilitate the understanding and interpretation of the data, direct quotations from the statements of the teacher candidates were included.

FINDINGS

The objective of this study was to demonstrate an exemplary application process for teaching DNA at the molecular level and to obtain teacher candidates' opinions on the process. The data pertaining to the answers given by the teachers to the semi-structured interview questions are presented in the tables below.

Firstly, teacher candidates were asked, "What do you think about the teaching process of the related subject (DNA)?". The codes and themes obtained from the answers given by the teacher candidates are given in Table 2.

Table 2. Teacher candidates' views on the teaching process of DNA

Theme	Code	Frequency (f)
Opinions on the teaching of DNA	I learnt the subject very well	14
	I reinforced my knowledge on the subject	9
	The subject matter was explained in all its details	9
	I learnt the subject permanently	8
	I learnt the subject through concretization of abstract concepts	4
	I understood the importance of the subject	2
Opinions on the application process	Many activities were carried out to support the learning process	11
	Different teaching methods/techniques were used	8
	Theory and practice were combined	8
	We were allowed to design materials	8
	We were taught how to do modelling	7
	A collaborative study environment was created	4
	Hands-on learning was practiced.	2
	Teaching in the classroom was supported by visual materials	1

When Table 2 is examined, answers given to the question can be categorized under two themes. Teacher candidates expressed their views on the implementation process under the two themes of Views on the Subject Matter of DNA and Views on the Application Process. Under the theme of opinions on the subject matter of DNA, teacher candidates mostly dwelled on the following: learning of the subject very well, reinforcement of their subject knowledge, and teaching of the subject in all its details. Under the theme of opinions on the application process, teacher candidates mostly dwelled on the following: carrying out of many activities to support the learning process, using of different teaching methods/techniques, and the combination of theory and practice. Direct quotations from the teachers' responses to the question are given below:

T1: "We used all kinds of methods in the process. We read books, summarized them in our notebooks, made models… I can say without a doubt that it was one of the subjects that I found the most challenging in the field of biology. But now I think that I have learned the subject thoroughly, helped by my own efforts and revisiting the subject now and then. Because using more than one teaching method on a subject enabled us to understand the subject matter in all aspects, and reinforce learning, and what we did not understand with one teaching method, was compensated for with another."

T5: "The teaching process was characterized by lots of activities supporting the process, and active hands-on learning. In particular, applied learning and take-home assignments led to a better understanding of the subject matter on a deeper level. The subjects were taught using the question-answer method using models supported with activities, which allowed a more permanent learning. Apart from all these, hands-on learning in a fun way accompanied by effective teaching allowed me to cultivate a more genuine interest in the subject matter and realize how important and amazing it is as a field of study."

After the first question, the teacher candidates were asked, “Were there any changes to your learning areas during the teaching process of the subject? How?” The codes and themes obtained from the answers given by the teacher candidates are given in Table 3.

Table 3. Opinions of teacher candidates on changes in learning areas

Theme	Code	Frequency (f)
Cognitive	I learned the subject in a meaningful way	10
	I gained new knowledge about the subject	8
	I can visualize the subject matter in my mind	5
	I learnt to think scientifically	2
	I started to make sense of what I read	1
Affective	I enjoyed the course	6
	There is more interest in the course	5
	I am more creative	4
	I gained a sense of responsibility	2
	I was happy to work in a collaborative environment	1
Psycho-Motor	I gained the skill of preparing materials	9
	I improved my manual skills	6
	I gained the ability to model my knowledge	6
	I gained the ability to use information in daily life	2
	I learned how to use different teaching methods/techniques in the classroom.	1

Looking at teacher candidates’ responses to the second question, we find that they are grouped under three themes: Cognitive, Affective and Psycho-Motor. Firstly, all teacher candidates answered the question by stating that there was a change to their learning areas. Looking at Table 3, teacher candidates mostly dwelled on the following when it came to the cognitive aspects of the process: meaningful learning of the subject, gaining knowledge about the subject and having a concrete picture of the subject. Secondly, it was seen that teacher candidates used codes indicating that they experienced affective learning. Most candidates stated that they enjoyed the lesson, they had more interest in the lesson and their creativity was improved. Finally, concerning the theme of psychomotor skills, most teacher candidates stated that they had gained material preparation skills, their manual skills had been improved and they had had the opportunity to model their knowledge. Direct quotations from the teachers' responses to the question are given below:

T6: “The teaching materials used contributed positively to my psycho-motor skills. I made an effort to find the correct material that matches the essence of the subject matter. I tried to come up with something more creative and thorough, thinking how I could use the material more efficiently in my future career.”

T16: “I think in a cognitive sense, my learning of DNA has visibly improved. Because not restricting myself to what is taught at the school, I did extra practice at home, which enabled me to grasp the subject matter more. My pscyho-motor skills improved thanks to material preparation assignments. Hands-on learning improved my manual skills and gave me a heightened sense of responsibility. Activity-based learning enables learners to take on more responsibility, while teaching collaborative learning, which exams cannot do. And that provides permanent learning.

Finally, teacher candidates were asked, "When thinking about the application process, what stage do you think contributed the most to you? Why?" The answers given by the teacher candidates are given in Table 4.

Table 4. Teacher candidates’ opinions on the stage which they think contributed the most in the application process.

Theme	Reason	Frequency (f)
Modelling	Enabled me to understand the subject better	10
	Enabled me to gain creative thinking skills	8
	Enabled hands-on learning.	7
	Provided a collaborative study environment	5
	Enabled me to gain three-dimensional thinking skills	5
	Concretized the subject	5
	Prepared me for my career	4
	Enabled permanent learning	4
Classroom	Taught the application of different teaching methods/techniques	6
	Reinforced learning	6
	Gave me new communication skills	4

activities	Provided an opportunity to exchange information	4
	Filled the gaps in my knowledge	3
Summarizing	Enabled me to go over the things learned in the classroom once again	6
	Made learning permanent	6
	Gave the opportunity to reinforce existing knowledge	4
	Enabled the recognition of vital aspects of the subject matter	2

According to Table 4, teacher candidates think modelling, classroom practices/activities and summarizing activities were the most fulfilling stages that contributed the most to their learning process. The reasons teacher candidates gave for choosing modelling were that the process allowed them to better understand the subject, gave them creative thinking skills, and enabled hands-on learning. Teacher candidates, stating that classroom practices/activities contributed more to the learning process, explained that these practices taught them how to use different teaching methods/techniques, reinforced their knowledge of the subject matter, and taught them communication skills. Finally, teacher candidates, who responded that summarizing content had made the greatest contribution, explained that summarizing allowed them to go over again what they had learned, made what they had learned permanent, and gave them the opportunity to reinforce their knowledge.

T8: "The designing of materials was what contributed to my learning the most. Because I think that hands-on learning makes a great contribution to permanent learning. I often used creative thinking and multidimensional thinking techniques. This will contribute not only to my studies, but also to my professional life. I think the group work we did in the classroom made me better understand the subject. The whole classroom connected really well. If we had just another exam at the end, we would probably forget most of our learning on the subject matter due to exam anxiety; so, permanent learning took place through the activities we did."

T9: "It was during the material preparation stage that most of the learning took place enabling me to reinforce my learning, while interaction with other classmates in the process allowed us to exchange knowledge and information. We worked mutually to complement our learning. It was truly beneficial in that regard.

In addition, I can now explain the subject with a material in my hand, without looking at any textbook. That prepares me for my future career. Finally, in modelling the sugar-phosphate binding of DNA in the classroom, I was able to cooperate with my classmates complementing the gaps in our learning, and the subject matter became more concrete in our heads helping us reinforce our learning. Without all these activities, it would not be permanent learning and it would be very difficult for me to understand the subject."

DISCUSSION AND CONCLUSION

In this study where a sample application for teaching DNA at the molecular level was developed and teacher candidates' views on this application were examined, the findings were obtained by analysing the answers given by teacher candidates to the semi-structured interview questions.

Firstly, teacher candidates were asked, "What do you think about the teaching process of the related subject (DNA)?". When the responses to this question were examined, it was found that teacher candidates combined this process with two themes, namely the subject matter of DNA and the application process. Using the sample application, teacher candidates used codes indicating that they learned the subject matter of DNA at a molecular level very well, reinforced their learning, that the subject matter was explained in all details, that the subject was concretized, and that they understood the importance of the subject matter. In terms of the application process, teacher candidates used codes indicating that many activities had been conducted, different teaching methods and techniques had been used, theory and practice had been combined, material design work had been done, modelling was taught, a collaborative study environment was provided, hands-on learning took place and the classed had been supported by visual materials.

After the first question, the teacher candidates were asked, "Were there any changes to your learning areas during the teaching process of the subject? How?" According to the responses of the teacher candidates, it was observed that they explained the changes in the learning areas under three themes: cognitive, affective and psychomotor. From the responses of teacher candidates who stated that the changes in the learning were cognitive, the following codes were extracted: I learned the subject in a meaningful way, I gained new knowledge about the subject, I can visualize the subject matter in my mind, I learnt to think scientifically and I started to make sense of what I read. From the responses of teacher candidates who indicated that the changes in their learning were affective, the following codes were extracted: I enjoyed the course, I had more interest in the course, I am more creative now, I gained a sense of responsibility and I was happy to work in a collaborative way. From the responses of teacher candidates who indicated that the changes in their learning improved their psycho-motor skills, the following codes were extracted: I gained the skill of preparing materials, I improved my manual skills, I gained the ability to model my knowledge, I gained the ability to use information in daily life, I learned how to use different teaching methods/techniques in the classroom.

Finally, teacher candidates were asked, "When thinking about the application process, what stage do you think contributed the most to you? Why?" From the teacher candidates' responses, it was concluded that they considered the application process in light of three themes: Modelling, Classroom Practices, and Making Summaries. Reasons cited by teacher candidates who responded that the modelling process had made the biggest contribution: Enabled me to understand the subject better, enabled me to gain creative thinking skills, enabled hands-on learning, provided a collaborative study environment, enabled me to gain 3D thinking skills, concretized the subject, prepared me for my career, enabled permanent learning. Reasons cited by teacher candidates who responded that classroom practices had contributed more: it taught the application of different teaching methods/techniques, reinforced learning, gave me new communication skills, gave the opportunity to exchange information and filled my knowledge gaps. Finally, reasons cited by teacher candidates who responded that summarizing content had contributed more: it allowed me to go over what had been learned, allowed permanent learning, gave me the opportunity to reinforce my learning and allowed the recognition of vital aspects of the subject matter.

Examining outcomes from studies using similar methods, techniques, and application processes in the teaching of DNA, they are completely consistent with the results reported by this study. For example, Malacinski and Zell (1996) stated that students who had difficulty learning micro-level concepts should be taught to concretize the subject matter of DNA and focus on visual materials. The study "Learning Genetics with Computer Dragons" by Tsui and Treagust (2003) created animations of genetic subjects with computer software called BioLogica using fabricated dragons. The results showed that these methods increased student motivation. It was observed that students participating in the study developed their understanding of genetics. Although genetic concepts are difficult to learn, abstract, and foreign students, it was concluded that BioLogica offers new opportunities for better learning of genetics. Similarly, Ash (2001) presented a model to explain the difference between genes and alleles and explained the concept of genome. Pieces of paper, pencils and dices were used in this model. As a result, it was suggested that students could understand and make sense of the concepts of gene, chromosome, DNA, RNA, and genetics using student-centered methods and techniques. On the other hand, Kirkpatrick, Orvis, and Pittendrigh (2002) developed a model in their study. In this model, an analogy was made between the structure of genetics and a town library, with Lego blocks. The transcription of the DNA molecule and its conversion into RNA in protein synthesis was explained using STAM. The study concluded the model constituted a new resource in teaching students the basics of genetics and biotechnology. Keles (2003) developed various classroom methods in teaching the DNA Watsons Crick model which he used inside the classroom. The study concluded that various classroom practices/techniques increased student success. Similarly, Karaman (2020) stated in his study that the use of argumentation-based concept cartoons increased students' academic success. In addition, Akgul and Colak (2021) studied the concepts of DNA and chromosomes with analogies, and stated that teaching with analogies increased academic success in teaching the subject of DNA. Similarly, Kocadag (2010) argued that scenario-based teaching materials increased the success of eighth grade students in teaching the subjects of heredity, DNA and genetic code and helped eliminate the misconceptions. In addition to these studies, Yurdatapan and Sahin (2013) also found that using animation and models in the teaching of DNA concepts caused a greater increase in academic success. There are many studies showing that various classroom practices can increase the academic success of candidate teachers in teaching the subject of DNA (Altinay, 2009; Altun, 2009; Yilmaz, Karakoc-Topal, & Oz Aydin, 2021). It is stated that classroom activities affect not only the academic success of the students but also impact on their attitudes positively in teaching the subject of DNA. For example, Karaman (2020), in his study using argumentation-based concept cartoons, argues that the process improves students' attitudes towards the lesson. Similarly, Aydogan (2019) argued in his study that the simulation-assisted cooperative teaching method caused the students to develop positive attitudes towards the lesson in the teaching of DNA. Finally, a study conducted by Yılmaz, Karakoc-Topal, and Oz Aydin (2021) with biology teacher candidates obtained their opinions on activities designed for the teaching of DNA. Accordingly, it was found that the students believed that the process of teaching with various classroom methods/techniques enables active learning, makes subject matter instructive and understandable, makes the lesson entertaining, attracts attention because it appeals to many senses, and provides permanent learning and understanding of the subject.

Biology subjects generally contain abstract concepts. One of these abstract, difficult-to-understand concepts at the molecular level is DNA. When the literature is examined, it is found that supporting instruction through various teaching practices in teaching hard to grasp subjects is effective in increasing success, and motivation and improving attitudes. In this context, this study developed a sample teaching practice/method in the teaching of DNA. The findings showed that teacher candidates who took part in the application had positive views about the teaching of the subject and the process. In the future, various other teaching practices for other abstract concepts in biology can be developed and the views of prospective teachers explored. The effects of these classroom practices on the academic achievements, attitudes and motivation etc. of teacher candidates can be examined.

Scientific Ethics Declaration
The authors declare that the scientific ethical and legal responsibility of this article published in JETT journal belongs to the authors.

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