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# Views of Middle School Students on the Effectiveness of Science Courses Conducted with Biomimicry

**Betül AYDIN** [1] **Fitnat KAPTAN** [2]

## Abstract

This study investigated the views of middle school students on the effectiveness of science courses conducted with biomimicry. To this end, phenomenological design, one of the qualitative research methods, was used. The study group consisted of 10 students in grades 5 and 7 who continued their education in a middle school located in the central district of Ankara province in the 2021-2022 academic year. Participants were determined through criterion sampling. The data collected through semi-structured interviews were analyzed using descriptive analysis. Based on the findings, codes and themes were created. According to the results of the study, students emphasized that science courses conducted with biomimicry activities increased their motivation and contributed to their academic and social development, as well as improving their creativity. In addition, due to the permanence of knowledge and the fun nature of the lessons, students also want to use biomimicry-based activities in other courses. In the study, how students overcame the challenges they faced was also examined. In this context, student responses indicated that the activities took too much time, they had difficulty deciding on the organism to be inspired by, and that a lot of thinking was required. Providing options for students to conduct biomimicry activities in areas of their interest will encourage greater participation. It is recommended to conduct more comprehensive studies on integrating biomimicry into science courses using different measurement tools and different study groups. It is thought that the widespread use of biomimicry activities will have a positive impact on students' motivation and academic achievement.

**Keywords:** Science Education, Qualitative Research, Biomimicry, Primary Education, Design

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# Ortaokul Öğrencilerinin Biyomimikri ile Yürütülen Fen Derslerinin Etkililiğine İlişkin Görüşleri

**Betül AYDIN** [3] **Fitnat KAPTAN** [4]

## Öz

Bu çalışmada biyomimikri ile yürütülen fen derslerinin etkililiğine ilişkin ortaokul öğrencilerinin görüşleri araştırılmıştır. Bu amaç doğrultusunda nitel araştırma yöntemlerinden fenomonolojik (olgubilim) desen kullanılmıştır. Araştırmanın çalışma grubunu 2021-2022 eğitim öğretim yılında Ankara ilinin merkez ilçesinde bulunan bir ortaokulda 5. ve 7. sınıflarda eğitime devam eden 10 öğrenci oluşturmaktadır. Katılımcılar gönüllülük esasına dayalı olarak ölçüt örnekleme yöntemi ile araştırmaya dahil edilmiş ve yarı yapılandırılmış görüşmelerle veriler toplanmıştır. Elde edilen veriler betimsel analiz yöntemiyle analiz edilmiştir. Görüşmelerden elde edilen bulgular doğrultusunda uzman görüşüne başvurularak kodlar ve temalar oluşturulmuştur. Araştırmanın sonuçlarına göre öğrenciler, biyomimikri etkinlikleri ile yürütülen fen bilimleri derslerinin eğlendirici olduğunu, anlamlı öğrenmelerini ve motivasyonlarını artırdığını, akademik ve sosyal açıdan katkılar sağlamasının yanında yaratıcılıklarını geliştirdiğini vurgulamışlardır. İlave olarak öğrencilerin bilgilerde kalıcılık sağlaması ve derslerin daha eğlenceli olması sebebiyle diğer derslerde de biyomimikri odaklı etkinlikler kullanmak istedikleri sonucuna ulaşılmıştır. Biyomimikri uygulamaları okul dersleri ile doğa arasındaki bağlantıyı göstererek öğrencilerin okula daha yakın hissetmelerine neden olmuştur. Bu sayede öğrenciler farklı bir bakış açısı ile doğayı gözlemlemeyi öğrenmiş, yeni ve benzersiz fikirler üretebileceklerini düşünmüşlerdir. Araştırmada, öğrencilerin öğrenme deneyimleri, yaşadıkları zorluklar ve bu zorlukların üstesinden nasıl geldikleri de incelenmiştir. Bu kapsamda öğrenci yanıtları etkinliklerin çok zaman aldığı, ilham alınan organizmaya karar vermede zorlandıkları ve çok düşünmek gerektiği yönünde olmuştur. Fen eğitiminde biyomimikri konusu genellikle çok fazla kavram bilgisi gerektirmektedir. Biyomimikri kavramını anlamaları ve canlı organizmaların özelliklerini öğrenmeleri, onların kendi tasarımlarını oluşturma konusunda motivasyon kazanmalarına yardımcı olacaktır. Biyomimikri etkinlikleri gerçekleştirirken öğrencilerin kişisel ilgi alanlarının da dikkate alınması önemlidir. Öğrencilere ilgi duydukları alanlarda biyomimikri etkinlikleri gerçekleştirmeleri için seçenekler sunulması, öğrencilerin etkinliklere daha fazla katılım göstermelerini sağlar. Biyomimikri etkinliklerinin yaygınlaştırılmasının öğrencilerin motivasyonunu ve akademik başarılarını olumlu yönde etkileyeceği düşünülmektedir.

**Anahtar Kelimeler:** Fen Eğitimi, Nitel Araştırma, Biyomimikri, İlköğretim, Tasarım

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## Introduction

For centuries, people have tried different ways to overcome difficulties. Engineers and scientists have been working to improve their design skills and solve design problems (Ceschin & Gaziulusoy, 2016; Gencer et al., 2020; Grant, 2012; Kelley et al., 2021; Lebdioui, 2022; Stevens et al., 2021). Nature has been a source of inspiration for scientists, engineers, and artists since the existence of humankind. This is because many of the problems we are trying to solve today have already been solved by nature. To effectively use materials, resources, and energy while solving problems, it is important to carefully observe nature (Altun, 2019; Benyus, 2002). Designs inspired by nature through biomimicry have been the focus of international interest for a long time, and many prestigious universities have established biomimicry research centers. For example, at Harvard University's Institute of Engineering Inspired by Biology, researchers' study how biological systems can be applied to engineering practices. The Biomimicry Center at Arizona State University research how problems solved by natural systems can be applied to engineering and technology fields. The center also examines ways to use various mechanisms in biological systems in areas such as production, energy, health, and the environment (Arizona State University, 2023). Similarly, the Biological Inspired Design Center at the Georgia Institute of Technology, the Interdisciplinary Biological Inspiration Center for Education and Research at the University of California, and the Biomimicry Research and Innovation Center at Akron University are leading biomimicry research fields affiliated with universities (CBID, 2023; CIBER, 2023; UA, 2023). These centers also offer various programs to educate students and equip them with knowledge and skills in the field of biological inspiration.

## Science Education and Biomimicry

The starting point for integrating biomimicry into educational processes is to question how nature addresses the difficulties that humans face (Benyus, 2002). This requires students to observe nature with curiosity and to see it as a teacher, to understand how living things overcome challenges such as feeding, sheltering, and living in communities (Benyus, 2002; Collins, 2016). This can only be achieved by incorporating biomimicry into science courses that are carried out in a planned manner (Avci, 2019; Staples, 2005).). Integrating biomimetic applications into topics in the science curriculum viewed through the lens of biomimicry will inspire students to emulate the functionality of nature in solving problems they encounter or will encounter in their daily lives (Çoban, 2019). The curriculum incorporating biomimicry will help teachers fulfill their teaching requirements in the classroom while emphasizing what students can learn outside the classroom (Say & Yıldırım, 2021). Interacting with nature in informal learning environments, such as hiking or spending time by a lake, naturally leads to curiosity, which prompts children to ask questions and develop creative ideas through their experimentation (Tisza et al., 2019). Additionally, interacting with living things helps students develop the ability to create sustainable designs and solutions (Eshach, 2007). There are many benefits to incorporating biomimicry into the science education curriculum, such as allowing students to make discoveries, providing a unique STEM (Science, Technology, Engineering, Mathematics) experience for students working in teams, encouraging students to design solutions for encountered challenges, developing skills in sustainability and creative thinking, and gaining different perspectives (Biomimicry Institute, 2006). Science classes that use biomimicry help

students understand the mechanisms of nature's wealth of solutions and how they can use them to solve problems while learning how nature can inspire innovative and sustainable design (Biomimicry Institute, 2006; Dilaver Türe, 2023).

In academic language, biomimicry is defined as a library where only successful solutions that have evolved over centuries are kept in nature (Biomimicry for Entrepreneurs, 2018). If students use biomimicry principles during learning from nature, the designed products will be environmentally sustainable products with high energy efficiency (Victoria & Krista, 2012). Integrating biomimicry into science classes can contribute to sustainability goals for our planet by creating interdisciplinary collaborations that can lead to new ideas (Jacobs, 2014; Jacobs et al., 2022; Linder & Huang, 2022; Staples, 2005). In short, biomimicry is a concept that helps in learning technologies developed by taking inspiration from nature and is therefore important in science education. According to Ersanlı (2016), students often question "why they need the information" and "where they will use what they learned" regarding physics topics. These questions indicate that students want to know how the information they learned can be applied in daily life. Answers to these questions can help clarify the importance and application fields of the topics, making the courses more meaningful and interesting. Biomimicry aims to teach students how natural systems work and their technological applications (Lebdioui, 2022; Lurie-Luke, 2014). This demonstrates to students how different branches of science, such as physics, chemistry, and biology, are related and how technology can be developed in these fields. Additionally, biomimicry teaches students to discover solutions available in nature and to develop new technological solutions through application. This helps students acquire problem-solving skills and gives them opportunities to understand nature and technology better (Ersanlı, 2016; Fried et al., 2020). The scientific disciplines supporting this goal are physics and the concept of biomimicry. By integrating topics such as how technologies developed from nature into physics education, courses can be made more meaningful and interesting. If students perceive that the knowledge of science has a direct connection to their experiences, their interest and attitude towards the subject will increase. For these reasons, it is important to understand what challenges students face in the implementation of biomimicry, which is a concept that adopts the idea of learning from nature, and what gaps exist in adapting this concept to science education.

When the literature is reviewed, it can be observed that the use of the term biomimicry has been increasing in different fields such as engineering, architecture, product design, etc. since the 1990s, and the number of studies investigating its position and importance in science education has also increased in recent years (Alemdar et al., 2021; Cakir, 2019; Canbazoğlu Bilici et al., 2021; Eagle-Malone, 2021; Kelley et al., 2021; Lebdioui, 2022; Mirici et al., 2021; Speck & Speck, 2021; Stevens et al., 2021; Sumrall et al., 2018). It can be observed that most of the research in this field is conducted at the undergraduate level with pre-service teachers (Cakir, 2019; Kandemir, Değirmenci & Coşgun, 2022; Kaya, 2022; Qureshi, 2022). Studies examining the opinions of science teacher candidates regarding biomimicry applications can also be found in the literature (Yıldırım, 2019). At the elementary level, studies have been conducted on the development of biomimicry instructional design within the scope of middle school Science Applications courses (Alperen, 2020), as well as on introducing the concept of biomimicry to first-grade students (Sumrall et al., 2018). It is observed that an integrated STEM lesson with biomimicry enables students to acquire knowledge about biomimicry

and science while developing language skills, logical reasoning, and mathematical thinking foundations (Dilaver Türe, 2023; Gould et al., 2021). Furthermore, biomimicry, due to its interdisciplinary nature, provides a significant positive contribution to students' learning in mathematics and science curricula (Karslı & Kurt, 2021). The use of biomimicry in science education provides an interdisciplinary approach that includes STEM education (Canbazoğlu Bilici et al., 2021; Kelley et al., 2021; Snell-Rood et al., 2021). Through this approach, students learn how to work across different disciplines and develop their creative thinking skills. Therefore, in order to achieve the goal of enriched science education with biomimicry activities, it is necessary to understand the thoughts of the target audience, namely students, regarding biomimicry education. This study aims to determine the positive and negative views of students regarding science courses conducted with biomimicry activities and their perceptions of the contribution of biomimicry-focused activities to their learning. Additionally, the study aims to identify the difficulties students face during biomimicry activities and their coping strategies. This study will serve as a reference for future similar studies and guide researchers working in this field. Considering all these reasons, the obtained data are expected to be meaningful and valuable in terms of literature. Within the context of this general aim, the following questions were addressed in this study:

Research Question:

What are the views of middle school students on the implementation process of biomimicry activities in science classes?

Sub-problems:

• What are the positive and negative opinions of middle school students about the implementation of biomimicry activities in science classes?

• What are the opinions of middle school students regarding the difficulties they experience during the implementation of biomimicry activities in science classes?

• What are the opinions of middle school students regarding the contribution of biomimicry activities in science classes to their development?

• What are the opinions of middle school students regarding the implementation of biomimicry activities in other subjects besides science classes?

## Method

### Design of the Research

Phenomenology is a design that focuses on individuals' daily life and social actions, providing an opportunity for the emergence of insights into the nature of reality (Merriam, 2013). This design is centered on phenomena that we are aware of but lack a detailed and comprehensive understanding (Yıldırım & Şimşek, 2011). Therefore, what holds significance in the phenomenology design is individuals' experiences and their experiences related to the phenomenon (Creswell, 2009). This study aims to deeply examine students' thoughts regarding biomimicry activities. For all these reasons, the phenomenology design, which aligns with the research objectives, has been chosen as the qualitative research method for this study.

### Ethical permission

The ethical suitability of the research has been determined by the decision of the Hacettepe University Ethics Committee dated 22/03/2022 and numbered E-35853172-399-00002111660 within the scope of the study.

**Research Group**

In studies designed with the phenomenology design, it is crucial to work with individuals who can contribute to the understanding of the phenomenon (Creswell, 2009). In this study, purposive sampling method of criterion sampling was preferred. In qualitative research, purposive sampling is recognized as a useful method for explaining and exploring phenomena (Merriam, 2013; Yıldırım & Şimşek, 2011). Criterion sampling involves selecting cases that meet specific criteria as determined by the researcher (Yıldırım & Şimşek, 2011). 8th-grade students are subjected to a centralized exam called the High School Entrance Exam (LGS), which creates pressure and stress on students (Atay, 2021; Kızkapan & Nacaroğlu, 2019; Şad & Şahiner, 2016). Due to the potential negative impact on the general psychological state, motivation, and participation of students involved in the research process, the study was not conducted on 8th-grade students. Karaman and Karaman (2016) stated in their study that the curriculum is intensive for 6th graders and considering that these factors could affect the results of the research and reduce the reliability of the findings, 6th graders were not included in the study. With the support of the school administration, the study was conducted with 5th and 7th-grade students, as they assisted in facilitating the implementation of the research at those levels. Therefore, for this study, a group of 10 students attending a middle school in Ankara during the 2021-2022 academic year was selected. The criterion used in the selection of the study group was their participation in biomimicry activities conducted within the scope of science classes. Ten students who volunteered to participate in the interviews were coded as S1, S2, S3, S4, S5, S6, S7, S8, S9, and S10. Descriptive information about the participants is given in Table 1.

**Table 1.** *Demographic Characteristics of Participants*

| Student Code | Gender | Age | Grade |
|---|---|---|---|
| **S1** | Male | 13 | 7 |
| **S2** | Female | 12 | 7 |
| **S3** | Female | 12 | 7 |
| **S4** | Female | 10 | 5 |
| **S5** | Male | 10 | 5 |
| **S6** | Male | 11 | 5 |
| **S7** | Male | 12 | 5 |
| **S8** | Female | 11 | 5 |
| **S9** | Male | 11 | 5 |
| **S10** | Female | 12 | 5 |

**Data Collection Tool**

A semi-structured interview was used as the data collection tool. In the semi-structured interview form, the researcher's questions are pre-prepared, but the order or details of the questions may change during the interview (Glesne, 2010). This allows the researcher to address new topics that may arise from the participant's responses.

The interview form questions were developed by relying on field notes. The prepared interview form was presented to an academician in the field of education and a science teacher specializing in the field of natural sciences, and opinions were obtained from these two experts. Based on the data gathered from expert opinions, the questions included in the interview form were evaluated in terms of comprehensibility, suitability, and adequacy, and necessary adjustments were made. For instance, to obtain more in-depth information regarding the challenges faced during the process of creating designs inspired by nature, sub-questions such as "What are the challenges you encounter in terms of time, environmental and economy?" were added. The interview form consists of two sections. In the first section, questions related to the participants' characteristics are asked, and in the second section, the participants' opinions on the implementation and effectiveness of biomimicry activities in the science of science are obtained.

**Data Collection Process**

The data for the research was collected in May 2022. Participants were informed about the purpose of the research and consent forms were obtained from them and their parents. Information was provided that audio recording would be conducted to ensure uninterrupted interviews, and the interviews lasted for 25 minutes. Information was also provided that all recorded data would only be used for scientific purposes and not for any other purpose and that a nickname would be used instead of the student's name. To increase internal validity, the interviews were conducted in a quiet environment and recorded using a sound recording device. The developed interview form was presented to an expert for their review, and necessary adjustments were made. In the findings section, participants' statements were presented through direct quotations to enhance internal validity. The characteristics of the participants in the study, the research methodology, the reasons for using this method, and the data were presented in detail to attempt to increase external validity. The findings were presented without interpretation, relying on direct quotes, and the generated codes-themes were adjusted based on expert input to enhance internal reliability. To ascertain the appropriateness of the research's results and findings, these two sections were presented to two expert science educators to seek external reliability.

**Data Analysis**

Descriptive analysis was used in data analysis. Descriptive analysis involves the description of data and the interpretation of these descriptions (Yıldırım & Şimşek, 2011). The aim here is to examine and understand the content of participants' responses after the interviews, as well as to classify the interview data into meaningful categories (Fraenkel & Wallen, 2011; Yıldırım & Şimşek, 2011). The data were separately examined by two different researchers, and codes were assigned based solely on participant responses. After the coding process, the researchers came together and, through iterative discussions and examinations, reached a consensus to create themes that encompassed the codes and organized the data into tables (Creswell, 2009). In the

created tables, sections were formed for participants, responses, codes, and themes to facilitate a detailed analysis of the data. Furthermore, to enhance internal validity, the researchers presented participants' views directly through quotations in order to interpret the findings.

## Findings

The responses obtained from the questions asked to the participants were examined, and the codes and themes created accordingly were presented in tabular form.

### Findings related to the 1st sub-problem

The codes obtained on the positive and negative thoughts of the students regarding science classes carried out through biomimicry activities were grouped under three themes and are presented in Table 2.

**Table 2.** *Perceptions Regarding the Incorporation of Biomimicry-Focused Activities in Science Classes*

| SAMPLE RESPONSES | CODE | THEME |
|---|---|---|
| Instructive | Learning | |
| Many people will invent | Acquiring knowledge | |
| Generate different ideas | Design | |
| Contributes to the lessons | Retention | |
| We get more information | New ideas | Cognitive |
| What we learned stays in our heads | Creativity | |
| There are more inventions | Discovery | |
| Our inventions increase | Teaching | |
| Permanence | Contribution to classes | |
| Teaches new things | Quick understanding | |
| Contributes to us | | |
| Stays permanently in our minds | Entertainment | |
| Foreseeing ability | Feeling good | |
| We learn faster | Foresight | Emotional |
| Enhances our imagination | Excitement | |
| Discover new inventions | Enthusiasm | |
| Come up with new ideas | Imagination | |
| Creative thinking | Freedom of thought | |
| Excitement of inventing | Having fun | |
| Desire to prepare | | |
| Freedom of thought has increased | | |
| My imagination has increased | Demanding | |
| A fun activity | Time-consuming | Negative |
| The lessons are entertaining | Requiring a lot of thought | |
| Science is better received | | |
| Entertaining | | |
| Thought of applying to real life | | |
| Takes time | | |
| Demanding | | |
| Needs to be thought about | | |

Students were asked, *"What are your positive and negative thoughts about the science class conducted with biomimicry activities?"* When Table 2 is analyzed, a large portion of student responses contain answers that the science class conducted with biomimicry-focused activities makes learning easier, they learn by having fun, the information is lasting, and they have more confidence in design making at the end of the process. The student with code S6 mentioned that the class is entertaining and interactive, which provides a chance for lasting learning, and they positively find the idea of applying the designs in real life. The same student also mentioned that they should think more about converting the knowledge about nature into design and therefore wanted the classes to continue for a longer time. The student with code S10 stated that the classes are interesting and entertaining, and this could have a positive effect on many people's creative thinking skills by saying, *"The classes are fun and maybe this will cause many people to invent things in the future."* The student with code S3 expressed both positive and negative opinions about the classes conducted with biomimicry as *"positively, the things we do are staying in my head. It's staying in my head because it's a bit of fun. Negatively, it's very tiring."*

It appears that the majority of participants believe that science courses conducted using biomimicry have contributed to their knowledge acquisition and development of creativity. Students S2, S5, and S7 expressed their thoughts as follows:

> The student with the code S2: "*I already love to invent. This way I get more excited. I've been eager to prepare constantly since you mentioned it last week, so I see this as very positive."*
>
> The student with the code S5: *"I think it made a big contribution. I mean, how to say creative thinking? Generating new ideas, producing different ideas, discovering new inventions, having a sense of foresight, creativity, and such things."*
>
> The student with the code S7: "*In our country or the world, new things are produced by taking inspiration from nature."*

**Findings related to the 2nd sub-problem**

The students were asked about the difficulties they faced in creating a design by taking inspiration from nature. The codes obtained for the difficulties encountered by the students were grouped under five themes and are given in Table-3.

**Table 3.** *Difficulties encountered in the design process.*

| SAMPLE ANSWERS | CODE | THEME |
|---|---|---|
| Drawing problems | Drawing | Cognitive |
| Disagreements | Information Access | |
| Access to materials | Decision Making | |
| Lack of permission to use certain materials | Idea Generation | |
| No problem | Excessive Thinking | |
| Difficulty in obtaining information | Research | |
| Decision making | Disagreement | Emotional |
| Fear of making mistakes | Fear of Making Mistakes | |
| Microscopes, electrical tools, and batteries are not available in the class | Lack of Time | Time |
| Idea generation | | |
| Experiment equipment is a bit expensive | Lack of Material | Physical/ Environmental |
| Lack of information | Lack of Laboratory | |
| Overthinking | Noise | |
| Difficulty in thinking | | |
| Research | Access to materials | Economic |
| Insufficient time | Expensiveness | |
| Stationeries are too expensive | | |
| A place with materials | | |
| The laboratory is larger and more inspiring | | |
| The laboratory inspires me | | |
| A quieter place could be better | | |
| Classroom | | |

The theme that students considered to have the most negative impact on their design creation process was identified as "*time*". Most students expressed this theme as *"not enough time"* and *"lack of time"*. The student with the code S5 faced difficulties while searching for animals to take inspiration from and finding their applications, as stated below:

> *"..first we identified several animals, I can't remember them now, it feels like I only remember what I'm doing now. Now we are identifying the animal, but we can't find its application. Or we say let's find one application or we can't find it, we can't find*

*which animal it is. I looked at a couple of them, one of the two worked but it wasn't very useful. In the end, we found what we considered to be the most appropriate."*

During the interviews, the laboratories were described by students as inspirational and encouraging places where they can find the materials they need. The lack of a laboratory was identified as a challenge in the design creation process. The statements from students highlighting this issue are as follows:

*"The laboratory comes to mind first as a wider and more inspiring place. The classroom is just a normal one, but when you go to the laboratory, it feels like you're doing something other than just having a lesson and it gives more inspiration."* (student with code S5)

*"Because in our classroom, as you know, there are no microscopes, electrical equipment, batteries, etc. We can find what we need in the laboratory."* (student with code S6)

*The s*tudent with code S8: *... the classroom is not very suitable, it's more suitable in the laboratory.*

Researcher: *Why?*

The student with code S8: *Because more objects meet our needs there."*

*"...yes, I don't think it was very suitable to be done in the classroom because there was not much material in the classroom and I think it would be easier if it was done in the laboratory because there was more material there."* (student with code S9)

*"... for example, there could be a place like a laboratory, with more books, a quieter place."* (student with code S2) Another challenge faced by students during the design process has been identified as the "economy" theme. Students with the codes S3 and S6 have reported difficulties related to this theme. An explanatory example is given below:

*".. so I didn't do anything because we didn't implement it. But another friend of ours could face an economic challenge because the experiment materials are a bit expensive right now"* (student with code S6).

**Findings related to the 3rd sub-problem**

Another research problem, *"What are the contributions of biomimicry applications in science class to students?"* was directed to the students. The codes obtained from interviews regarding the contributions of biomimicry-focused activities to students were grouped under three themes, as shown in Table 4.

**Table 4.** *Contributions of Biomimicry Applications to Students.*

| SAMPLE ANSWERS | CODE | THEME |
|---|---|---|
| My research interest increased | Beneficial for exams | |
| My drawing ability improved | Generation of new ideas | |
| It facilitated our socializing | Learning | |
| We can invent more | Planning | Academic |
| It contributes to our minds | Retention | |
| Positive from academic, social, and creative aspects | Teachability | |
| It strengthened our friendship relationships | Scientific mindset | |
| We can develop inventions | Experimentation | |
| Expanded our imagination | Enthusiasm | Social |
| We acted like scientists | Socialization | |
| Expanded our minds | Strengthening relationships | |
| Our thinking improved | Imagination | |
| My imagination increased | Ability to design | Creativity |
| We made plans | Drawing ability | |
| Learned what we didn't know | Thinking | |
| Classes were memorable | Better designs | |
| Learned through experimentation | Innovation improvement | |
| Beneficial for exams | | |
| Informs people | | |
| Can achieve better designs | | |

When Table 4 is analyzed, the contributions provided by biomimicry activities are examined based on the views of the students under the themes of academic, social, and creativity. Academically, a student with code S1 described the contribution of the activities as *"because it opens the mind"*. The student with code S5 stated that reviewing data, researching, and designing processes enhances thinking skills and expands their knowledge. They stated *"We re-examine what we know in our brain through the activity. If we don't find something appropriate, we start the research process. After that, we think about what materials we can use, and how we can use them, and we go through that process. In the end, when we start making, something different comes up, and we try to make that, and in this way, we expand our minds. We may also learn some new things we don't know about."* In terms of creativity, student with code S10 said that the activities could have an impact, increase the research desire, and improve drawing skills if working on drawing. However, the student who is identified by the code S3, stated that they did not experience a change in their creativity as follows:

A student with code S3: *"So, we are all still creative, no change.*

Researcher: *You consider yourself to be creative before.*

A student with code S3: *Yes, we just put it into practice, so to speak."*

A student with code S4 student stated that in science classes conducted with biomimicry activities, they work like a scientist who "*invented the telephone*," and emphasized the need for observation, planning, and prediction during the design process, in other words, using scientific process skills.

A student with code S6 student, who emphasizes the permanence of the information obtained in science class and believes that this leads to more effective learning and increased academic success, said, *"As I mentioned earlier, it helps the class stay in your mind. We don't have any difficulties in exams or oral exams."*

When the contribution of biomimicry-focused activities in science classes is investigated under the theme of "social," the student perspectives explaining this situation are given below:

S9: *"Positive from a social aspect, like group work. If it was individual work, maybe you know something that the other side doesn't. You'll learn that. Or the other side knows something you don't. This way, in group work, two, three, or four of us come together and it becomes better."*

S6: *"I think it has no or little contribution (from a social aspect). Because we're trying to reach a common path with our friends. That's what contributes from a social aspect."*

When the contribution of biomimicry activities under the theme of "creativity" is analyzed, the S9 expresses their opinion as follows*: "It promotes our socialization... and also expands our freedom of imagination, and especially when our imagination is wider, we can invent even more."* The same student was asked, *"Do you think it has a contribution from a creativity aspect?*" and responded, "*Of course, it does. Because an experiment is essentially about creativity."* These statements indicate the students' belief that their creativity has developed.

*"Yes, before, I couldn't do certain things, but now with biomimicry, I can obtain better designs."* (Student with code S7)

*"In my opinion, creativity will be the most significant thing. Especially in terms of design. Now, we first think about what to do with a model, whether to draw a picture or describe it. Now, while reviewing these three, I think about how I can make the model, what do I need? How can I draw, what do I need? How can I write, how can I describe? That's why we choose the best one for us, and we can create a beautiful structure from here, in my opinion, that's why it's useful."* (Student with code S5)

**Findings related to sub-problem 4**

The codes obtained from the students' opinions regarding the effectiveness of biomimicry applications in other subjects are gathered under three themes and presented in Table 5.

**Table 5.** *Use of Biomimicry in Other Subjects*

| SAMPLE ANSWERS | CODE | THEME |
|---|---|---|
| "Yes, because it contributes to our love for classes"<br>"Yes, because classes become more fun" | Class enjoyment<br>Finding the classes fun | Emotional |
| "Yes, because we become more active"<br>"Yes, because our grades go up a little bit" | Permanent retention of information<br>Active learning | Cognitive |
| "Yes, because it's better retained in our minds"<br>"Yes, because classes sink in better in our minds"<br>"In Turkish, Social Studies, Mathematics, all subjects"<br>"No, because it would be boring in every class"<br>"No, because the subjects like the universe and animals do not exist in other classes"<br>"No, because this topic is specific to Science class." | Boredom<br>Not appropriate | Negative |

Students were asked if they would like to apply biomimicry-focused teaching in other lessons, and codes and themes were created based on the responses received. According to Table 5, students want biomimicry activities to be implemented in other lessons under 'cognitive' and 'sensory' themes. Students with codes S6 and S7 expressed their opinions in Turkish class, students with codes S10 and S7 expressed their opinions in the Social course, S2 expressed their opinions in the Mathematic course, and student with code S5 expressed their opinions for all courses to include biomimicry activities. They stated that they want this to happen because they want the topics to be more lasting and to improve their grades. S2 explained his opinion by saying, *"I think that if biomimicry is applied in the classes we don't like, it will contribute to our liking those classes because it is such a fun topic."*

> S7: *"Because biomimicry brings to life in my mind better and sticks better in my brain, I would like it to be applied in other subjects...for example, Turkish. Turkish and Social studies.*
>
> Researcher: *Why did you want it to be in those subjects?*

S7: *Because, as I stated, I have difficulties with those subjects, so I would like biomimicry to be applied so that I can understand the subjects more easily."* The student states that they find it easier to understand the course topics they have difficulty expressing in words with biomimicry activities.

S3, a student identified with the code S3, explains that they do not want the same approach used in every class, unlike other students:

S3: "*No, I don't want it to stay that way if it's just in one class."*

Researcher: "*Why is that?"*

S3: "*Because I think one class is enough... I don't know, maybe it gets repetitive."*

A student identified with the code S6 thinks that using biomimicry-focused teaching in other subjects doesn't make sense because they only see it as related to science classes:

Researcher: "*Would you like biomimicry-focused teaching to be applied in other subjects?"*

S6: "*Honestly, I think it's a bit silly to do a bit of biomimicry in other classes as well because it's related to science. For example, Turkish, Turkish words, grammar, and stuff like that, but in science, we understand the whole universe, and we can invent. We are inspired by animals, we see animals."*

## Discussion

This study investigated the views of middle school students on the use of biomimicry activities in science courses. In this context, students' perceptions of science classes conducted with biomimicry activities and the effectiveness of the implementation, as well as the difficulties they encountered during the implementation and whether biomimicry-focused activities contributed to them, were attempted to be revealed.

In the first sub problem, students were asked to express their general opinions on the implementation of biomimicry activities. The responses obtained from the students' opinions were coded and grouped under 'cognitive, emotional, and negative themes. Most students stated that science classes that focus on biomimicry activities are entertaining and that their confidence in design increased at the end of the process. Participants frequently mentioned that they could generate new ideas and that their creativity had improved. Similarly, Gencer et al. (2020) conducted a study with 21 students who were in the 5th grade of a state middle school. They asked the students to identify a problem and develop a possible solution using biomimicry as part of STEM applications. When the results of the study were analyzed, the students stated that even though they faced some difficulties in the biomimicry design process, they liked everything about the activity. According to the participants' opinions, the classes that were described as fun were also more memorable. The results obtained support the literature that states that making a class fun facilitates learning (Dönel Akgül & Kiliç, 2023; Karamustafaoglu et al., 2016) and that activities in science classes contribute to students' creative thinking skills (Özkale et al., 2020).

Some participants emphasize that biomimicry activities require a lot of time and energy, making them challenging. Although practical skills are given to students, activities that they may have to do in biomimicry activities include analyzing natural systems or

organisms, designing, or producing. Therefore, despite the students being informed about biomimicry, it is still possible to find studies where they do not use or do not want to use this method in their designs, similar to participants who describe the activities as challenging (Boga & Timur, 2016). The contribution of biomimicry to education should not be limited to improving teamwork, and social, and personal skills. Again, upon examination of the literature, some studies indicate that it allows learning to have a more positive response when encountering difficulties or negative results during the design creation process (Speck & Speck, 2021). Personal skills such as patience and understanding can also be developed in the event of failure, thereby preserving motivation and achieving a better result by trying again, which are also among the outputs of the process.

Another sub-problem of the study is concerned with the difficulties encountered during activities. The responses obtained from the students' opinions were coded and grouped under cognitive, emotional, time, physical/environmental, economic themes. Most participants mentioned time constraints as the main difficulty, followed by a lack of materials and issues related to the environment such as noise. Similar findings were found in previous studies, for example, insufficient time allotted for activities (Şahna & Başbay, 2013) and noisy environments and fear of failure during structured activities (Biyikli & Yagci, 2014) were common challenges. Most students also indicated that they prefer to conduct biomimicry activities in the laboratory to have easy access to the materials they need. The study by Swarat, Ortony, & Revelle (2012) aimed to address the lack of information on what makes science courses interesting for students. Interviews were conducted with 10 students to better understand the impact of learning environment elements (topic, activity, and learning goals) on students' interests. The study found that activities that are practical and allow interaction with technology tend to generate more interest among students. Emphasizing the role of activities in creating engaging learning environments can help develop students' interest in science. Biomimicry activities allow students to actively participate in the learning process and can increase their motivation by providing hands-on experience and gaining knowledge. Biyikli & Yagci (2014) stated that material-related problems encourage students to collaborate and share, leading to the development of different skills.

The third sub-problem of the research was to gather opinions on the contribution of biomimicry activities to students. The responses obtained from the students' opinions were coded and grouped under academic, social and creativity themes. A large majority of students stated that their creative skills, such as imagination and ability to design and invent, have improved under the theme of "creativity". Similarly, literature in the field also suggests that widespread implementation of biomimicry design works at all education levels will enhance problem-solving, design skills, collaboration, and analysis, as well as increase research curiosity and imagination among students (Avci, 2019; Gencer et al., 2020; Gould et al., 2021; Grant, 2012; Jacobs et al., 2022; Kelley et al., 2021; Nicholas & Peterson, 2015; Staples, 2005; Stevens et al., 2021; Williams et al., 2019;). Participants also emphasized that courses based on biomimicry activities increased their research needs and imagination, leading to better designs.

Finally, opinions on the effectiveness of biomimicry applications in other courses were collected during the research process. The responses obtained from the students' opinions were coded and grouped under emotional, cognitive negative themes.

Students have indicated that they would like to use biomimicry in other courses because it makes classes more fun, they are more active, they achieve academic success, and it helps retain information. Student responses were concentrated on Turkish, Social Studies, and Math classes. However, opinions were also gathered from participants who believed that biomimicry could not be used in subjects other than science. Biomimicry is an approach that uses the designs and functions of nature in human-made systems. Biomimicry can be applied in subjects other than science. For example, in Turkish classes, biomimicry allows students to examine natural language usage and understand the design of natural language. By using biomimicry in Turkish classes, students' sensory experiences in learning the language can also be increased. For example, by taking inspiration from bird species that learn sounds by recognizing and imitating them (such as crows and nightingales), sound examples can be shared with students, encouraging them to recognize and imitate sounds. In math classes, biomimicry allows students to examine the mathematical laws of natural events and apply them. Similarly, by taking examples of spiral structures in nature, geometric structures and their properties like spirals can be shared with students in mathematics. In social sciences, biomimicry allows students to examine the structure and functioning of natural societies and question whether these structures and functioning can be applied to human-made societies.

Based on the findings of the study, it has been observed that biomimicry activities are positively received by students, and participants have indicated that these activities make science classes more enjoyable and contribute to the development of students' creativity and problem-solving skills. Biomimicry activities have instilled confidence in students to generate new ideas and engage in design processes, allowing them to experience scientific procedures. Furthermore, it has been emphasized that biomimicry activities can be applied in other subjects as well, offering students a fun and effective learning experience in diverse disciplines. These findings shed light on the potential impact of biomimicry in education, making them a valuable reference for educators and researchers.

## Conclusion

As science and technology rapidly advance, individuals must be open to innovation. Therefore, it is of great importance to educate individuals who can keep up with changing technology and contribute to its development. This is where biomimicry comes in, where we can look to nature as a research and development laboratory. Observing how nature uses renewable resources, limits waste production, and maintains products without polluting the environment will inspire us to design with a low ecological footprint.

Biomimicry-based education is not only a great way to engage students with real-world environmental literacy problems, but it also provides them with applicable solutions and a hopeful outlook for the future of our planet (Biomimicry Institute, 2006). Therefore, incorporating the study of the ways of life and models of nature in science classes and questioning how nature copes with challenges can create a new understanding in education.

This study is limited to ten secondary school students trained in biomimicry activities. In future studies, the effectiveness of the education can be more clearly demonstrated

through an experimental study by including student groups and teachers from different grade levels. The results of this study are limited to ten middle school students and the semi-structured interviews conducted with them. To examine whether the data varies based on different demographic characteristics of students, quantitative studies covering the entire class can also be considered. Additionally, it is considered beneficial for the field literature to conduct a different qualitative study that involves a long-term observation of teachers' instructional practices through an action research approach, which would provide more in-depth data.


| | |
|---|---|
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