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RESEARCH ARTICLE

Views of Biology and Science Teachers on Biomimicry*

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ABSTRACT

The aim of this study is to determine the views of biology and science teachers regarding biomimicry. Phenomenology, one of the qualitative research methods, was used to obtain data for the purpose of the study. The study group consisted of 19 teachers who work as biology and science teachers in public institutions affiliated with the Ministry of National Education in Ankara. Criterion sampling was preferred in the selection of the study group since interviews were conducted with teachers who met certain criteria. A semi-structured interview form titled "Biology and Science Teachers' Views on Biomimicry Interview Form," prepared by the Researchers, was used as the data collection tool in the study. The interviews conducted during the implementation process of this research were carried out both face-to-face and online. The data in this study was evaluated using the content analysis method. The results obtained in the study showed that teachers were familiar with the concept of biomimicry, but some teachers experienced conceptual confusion. At the same time, this study revealed that when teachers used biomimicry for various purposes in their lessons, it made multifaceted contributions to the lessons and students. In addition, teachers made suggestions for biomimicry to be included more in textbooks, curriculum, printed and digital resources, teacher trainings and student workshops.

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1. Introduction

From the beginning of human history, it is known that humans have observed nature to protect themselves, sustain their lives, and make their existing lives more manageable (Say & Yıldırım, 2021). As a consequence of humans being inspired by nature, the concept of Biomimicry (Biomimetics) was introduced. The term "biomimicry" was first used by Janine Benyus in 1997. It is derived from the combination of two words: "bio," meaning life, nature, or living, and "mimicry," meaning imitation (Benyus, 2002; Yıldırım, 2019). When used together, these terms signify the imitation or emulation of nature (Mahgoub & Alawad, 2014). In her book *Biomimicry*, Benyus (2002) emphasizes the critical role of biomimicry in fostering innovative ideas by encouraging scientists to study the functional principles of plants, animals, and both living and non-living systems in nature (Avcı, 2019). Acting as a bridge that integrates various disciplines, particularly biology, biomimicry has become a widely utilized approach in the scientific community today (Avcı, 2019; Shimomura, 2010). With the changing times and advancing technology, there has also been a growing interest in innovative approaches in educational curricula, leading to the gradual incorporation of

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biomimicry applications, which blend nature and technology, into teaching practices.

In contemporary educational systems, it is recommended to provide a curriculum that emphasizes the development of inquiry and problem-solving skills, integrating innovative learning methods throughout the process. It is also emphasized that learning environments should be collaborative, enabling students to connect their learning with real-world contexts through projects and practical applications (Avcı, 2019).

Biomimicry is a powerful approach in science education, enhancing students' scientific and creative thinking skills, strengthening their connection to nature, and fostering a sense of environmental sustainability. In line with the goals of science education, biomimicry offers a learning framework that brings together multiple disciplines to cultivate environmentally conscious global citizens who understand their integral role in the natural world. Moreover, it plays a critical role in nurturing students as individuals who appreciate the natural environment around them and make positive contributions towards shaping a more sustainable planet (Çoban, 2019).

Projects inspired by nature increase students' engagement in active learning processes, reinforcing their interest in science and technology. Therefore, integrating biomimicry-based teaching approaches into educational curricula can provide students with a more comprehensive learning experience.

An examination of the specific objectives outlined in the Biology Curriculum prepared by the Ministry of National Education in 2018 reveals the following goals:

- Objective 2: Developing the ability to apply biological knowledge and practices in daily life.
- Objective 5: Encouraging students to generate new ideas and engage in original projects using the knowledge, skills, and competencies acquired in biology courses.
- Objective 7: Fostering awareness of technologies inspired by living organisms and motivating students to innovate in similar ways (MoNE, 2024).

Similarly, the curriculum includes the learning outcome, "9.3.2.2. Explains the contributions of living organisms to biological processes, the economy, and technology, and provides examples of technologies inspired by living organisms," which clearly aligns with biomimetic principles (MoNE, 2018).

Furthermore, the Science Curriculum aims to cultivate science and technology literate individuals who can use their scientific knowledge and skills to solve real-world problems, make informed decisions with scientific understanding, and take responsible, innovative actions (MoNE, 2018).

When the goals and outcomes within these curricula are considered, it becomes evident that linking the knowledge derived from nature and living organisms to real-life applications is highly valued. Given that the biomimicry process involves studying, examining, and drawing inspiration from the characteristics of living organisms to develop innovative solutions, incorporating this approach into lessons and projects is considered essential for meaningful science education (Ergül, 2023).

A review of the relevant literature reveals a number of studies on biomimicry conducted with preservice teachers enrolled in education faculties (Çakır, 2019; Fried et al., 2020; Gökgöz, 2022; Kandemir et al., 2022; Kaya, 2022; Mirici et al., 2021; Qureshi, 2020; Tavşan, 2022; Yıldırım, 2019). Similarly, research involving primary and secondary school students is also present in the literature (B. Aydın, 2023; D. Aydın, 2023; Çoban & Coştu, 2023; Çoban, 2019; Dilaver Türe, 2023; Özdemir & Mirici, 2022; Terzi, 2023; Ülbeği Ülker, 2023; Uluçınar Sağır et al., 2022; Yakışan & Velioğlu, 2019; Yıldız, 2023). However, there appears to be a gap in the literature regarding studies conducted with in-service biology and science teachers. This research, therefore, aims to address this gap by focusing on biology and science teachers, contributing to the existing body of literature in this emerging field.

In order to cultivate scientifically literate and entrepreneurial individuals, which are among the 21st century skills emphasized in educational curricula, it is essential for teachers to have a deep understanding of nature, recognizing its complex systems and vast interconnections (MoNE, 2018). As the primary facilitators of learning, teachers play a critical role in integrating biomimicry concepts into their teaching practices, guiding students to draw inspiration from the natural world. Given that biology and science are disciplines inherently focused on the study of nature, it is vital for teachers, as well as society as a whole, to be aware of biomimicry as a scientific field that draws inspiration from nature to develop innovative designs and solutions.

Therefore, this study aims to explore the perspectives of biology and science teachers regarding biomimicry. Within this framework, the following sub-questions have been formulated for the study:

1. What is the teachers' prior knowledge about the concept of biomimicry?
2. How do teachers incorporate biomimicry into their lessons?
3. Why do teachers choose to use biomimicry in their teaching?
4. What contributions does biomimicry make to their teaching practices?
5. What challenges do teachers encounter when using biomimicry in their lessons?

6. What are teachers' recommendations for integrating biomimicry into their lessons?

2. Method

The study protocol was approved by Gazi University Ethics Committee with the decision number E898063 on 06.03.2024.

2.1. Research Design

In this study, which aims to investigate the perspectives of biology and science teachers on biomimicry, phenomenological design, one of the qualitative research methods, was employed. Phenomenological research focuses on how individuals experience a given phenomenon through methodical, in-depth, and carefully constructed descriptions (Patton, 2014). In this context, the phenomenon to be thoroughly examined in this study is defined as the perspectives of biology and science teachers regarding the concept of biomimicry.

2.2. Study Group

The study group for this research consists of 19 teachers currently employed as biology and science teachers in public schools affiliated with the Ministry of National Education in Ankara. Given that the study involved interviews with teachers meeting specific criteria, criterion sampling was chosen as the sampling method. Due to the compatibility of biology and science curricula with the use of biomimicry, teachers of biology and science who will teach these subjects were selected through criterion sampling. This approach involves selecting participants based on predefined criteria. In this study, the criteria required that participants be either biology or science teachers actively engaged in the teaching profession. Detailed information regarding the participants in the study group is presented in Table 1.

Table 1. Demographic information of the participants.

Participant Code	Gender	Age	Professional Seniority	Education Status	Branch	Teaching Level	School Type
T1	Women	38	14 Year	Master's Degree	Science	Middle School	Middle School
T2	Women	36	10 Year	Master's Degree	Biology	High School	Science High School
T3	Women	40	18 Year	Master's Degree	Science	Middle School	Middle School
T4	Men	44	24 Year	License	Biology	High School	Anatolian Imam Hatip High School
T5	Women	46	24 Year	License	Science	Middle School	Imam-Hatip Middle School
T6	Women	39	18 Year	License	Science	Middle School	Imam-Hatip Middle School
T7	Women	39	16 Year	Master's Degree (Continue Doctorate)	Science	Middle School	1.Evening Art School
T8	Men	37	12 Year	Master's Degree (Continue Doctorate)	Science	Middle School	Science and Art Center
T9	Men	47	25 Year	Master's Degree	Biology	High School	Science High School
T10	Women	39	16 Year	Master's Degree with Thesis/ Master's Degree without Thesis	Biology	High School	Vocational and Technical Anatolian High School
T11	Women	52	29 Year	Master's Degree	Biology	High School	Science and Art Center
T12	Men	39	12 Year	License	Science	Middle School	Middle School
T13	Women	45	25 Year	License	Biology	High School	Science High School
T14	Women	36	11 Year	License	Biology	High School	Science High School
T15	Women	39	11 Year	License	Science	Middle School	Middle School
T16	Women	51	28 Year	License	Science	Middle School	Middle School
T17	Women	52	20 Year	License	Science	Middle School	Middle School
T18	Women	52	28 Year	License	Biology	High School	Science High School
T19	Women	53	30 Year	License	Biology	High School	Science High School

As shown in Table 1, the study group consists of 15 female and 4 male participants. To ensure the confidentiality of the participants' identities, each teacher was assigned a code ranging from T1 to T19. Of these, nine teachers are biology teachers at the high school level, while ten are science teachers at the middle school level.

Among the high school teachers, one works at a Science and Art Center (BILSEM), six at science high schools, one at a vocational and technical Anatolian high school, and one at an Anatolian Imam-Hatip high school. At the middle school level, one teacher is employed at a BILSEM, two at Imam-Hatip middle schools, one at a first evening arts school, and six at regular middle schools.

The ages of the participating teachers range from 36 to 53 years, with professional experience spanning 10 to 30 years. Regarding their educational backgrounds, 11 teachers hold bachelor's degrees, five have completed master's degrees, one has both thesis-based and non-thesis master's degrees, and two are currently pursuing doctoral studies.

2.3. Data Collection Tools

In this study, data were collected using a semi-structured interview form titled "Biology and Science Teachers' Perspectives on Biomimicry," which was developed by the researcher.

2.3.1. Interview Form on the Perspectives of Biology and Science Teachers on Biomimicry

The interview form was designed in accordance with the main objectives and sub-objectives of the study, informed by an extensive review of the relevant literature. To assess the appropriateness and clarity of the questions, expert opinions were obtained from six independent scholars: three specializing in biology education, two in science education, and one with expertise in qualitative research methodologies. The feedback received from these experts was jointly evaluated by the researcher and the academic advisor. As a result of this evaluation, certain questions were reformulated as sub-questions, and revisions were made to the sentence structures of some items to enhance clarity and coherence. Following these modifications, the final version of the form included a total of 15 open-ended questions, comprising 9 main questions and 6 sub-questions.

2.3.2. Validity and Reliability

In order to ensure the validity and reliability of the research data, the criteria of credibility, dependability, transferability, and confirmability, as proposed by Lincoln and Guba (cited in Creswell, 2016), were addressed. One of the strategies employed to enhance credibility was expert review, which involves the evaluation of the study by experts from various perspectives (Merriam, 2013; Yıldırım & Şimşek, 2013). In this context, expert opinions were obtained regarding the open-ended interview form developed by the researcher. The draft of the interview form was submitted to six experts, and their suggestions were evaluated jointly by the researcher and the academic advisor, after which the final version of the interview form was established.

To facilitate readers' judgments regarding transferability, rich and thick descriptions were provided, including direct quotations from participants. Additionally, detailed explanations of the participants' characteristics were included to support transferability (Merriam, 2013).

Confirmability, which corresponds to the criterion of objectivity, refers to the extent to which the findings and interpretations are grounded in the data and derived through a reliable and transparent inquiry process (Lincoln & Guba, 2013). To ensure dependability, the research data were analyzed independently by two separate researchers. Each researcher conducted an independent analysis of the qualitative data, and the results were then compared collaboratively.

To test the reliability of the coding process, the formula proposed by Miles and Huberman (1994) was used:

Reliability Percentage (P) = (Agreement (Na) / (Agreement (Na) + Disagreement (Nd) x 100

In qualitative research, a reliability percentage of 70% or above is considered acceptable (Miles & Huberman, 1994). In this study, the data were analyzed independently by two researchers, and the inter-rater agreement was calculated. The agreement percentage was found to be 85% with the first researcher and 87% with the second. To minimize discrepancies between the researchers' interpretations, these results were discussed, and consensus was achieved through negotiation.

2.4. Data Collection

The interviews conducted for data collection were scheduled by arranging appointments with the participating teachers on mutually agreed dates and times. Eleven of the interviews were conducted face-to-face, while eight were conducted online due to the teachers' demanding work schedules. Prior to each interview, the purpose of the study was explained to the participants, and their consent was obtained regarding audio and video recording. All teachers consented to audio recording, and some participants also agreed to video recording.

The duration of the interviews varied between 8 and 40 minutes, depending on the depth of the teachers' responses. The teachers responded to the questions verbally, and the collected data were transcribed verbatim into a digital document, resulting in a total of 39 pages of text.

2.5. Data Analysis

In this study, the collected data were analyzed using the content analysis method. Content analysis is an analytical approach that aims to examine the data in depth and generate concepts and categories (Yıldırım & Şimşek, 2013). Since no prior study was found on this specific topic, the codes and categories were derived directly from the data, and an inductive content analysis approach was adopted (Hsieh & Shannon, 2005). Categories were created by grouping multiple codes or subcategories that reflected a common pattern or idea (Creswell, 2017).

The data were gathered through a semi-structured interview form administered to 19 teachers. During the analysis, the teachers' statements were coded in line with the research objectives, and these codes were then organized into categories and subsequently into overarching themes. While identifying subcategories, the researchers remained as faithful as possible to the original expressions of the participants. In some cases, teachers' responses addressed more than one theme and/or category, which resulted in frequency values exceeding 19. The findings were presented through frequency tables along with the researcher's interpretations. Direct quotations from the participants were also included in the findings. To maintain anonymity while preserving authenticity, the teachers were coded as T1, T2, and so forth.

In the next stage, codes were created to determine under which categories and themes the data should be classified. These codes were grouped under preliminary categories based on the frequency of specific expressions used by the teachers. This coding process was independently conducted by two subject-matter experts. At the end of this process, similar codes were used to define categories, and the corresponding themes for these categories were identified. The categories and themes developed by the two experts were then compared, and adjustments were made based on the observed similarities and differences. Finally, the resulting categories and themes were reviewed by a third researcher. The inter-coder reliability among the experts was assessed to be high.

3. Findings

In this study, which aimed to gather teachers' perspectives on the concept of biomimicry, a semi-structured interview form was administered to 19 teachers included in the research.

3.1. Teachers' Prior Knowledge of the Biomimicry Concept

When analyzing the responses to the questions related to the first sub-problem, which aimed to explore teachers' prior knowledge of the concept of biomimicry, it was found that all participating teachers reported having previously encountered the term.

An additional question was posed to participants to identify the sources from which they had acquired their knowledge of biomimicry. The responses, categorized under the theme of "sources of biomimicry knowledge," were grouped into five main categories: formal education, books/articles, curriculum, personal interest, and other. The majority of teachers indicated that they first encountered the concept of biomimicry during their formal education, particularly at the university level. Similarly, the second most common category (f=7), books/articles, revealed that many teachers became familiar with biomimicry through exposure to the concept in textbooks, academic books, and scientific articles during their professional careers.

Another prominent category (f=6) was the curriculum. Several teachers noted that the concept had been included in previous high school curricula, leading them to address it in their lessons. For instance, one participant (Teacher 6) shared, "There was a reading passage titled 'Nature-Inspired Imitations' in the 7th grade ecosystems unit," indicating that biomimicry is sometimes introduced as supporting content within science textbooks. This observation suggests that the concept, though brief, is occasionally incorporated into science curricula as a supplementary idea.

Overall, the interviews highlighted that science teachers, in particular, encounter the concept of biomimicry more frequently within the context of their teaching topics.

For the second question, teachers were asked to define the term "biomimicry." The responses were grouped into two main categories: "imitation" and "designing new products/designing." The term "imitation" emerged as the most commonly used descriptor (f=16), with many teachers defining biomimicry as the process of creating new products or designs inspired by the imitation of nature, living organisms, and animal behaviors.

However, a noteworthy finding from the interviews was the conceptual confusion between "biomimicry" and "mimicry," as some teachers appeared to use these terms interchangeably. For example, Teacher 18 defined it as "Imitation. It can be described as one species imitating the similar features of a closely related species," while Teacher 9 stated, "There are various definitions related to biomimicry. For instance, imitating an animal's behavior," reflecting this misunderstanding.

As a follow-up to the second question, teachers were also asked about the disciplines that might be involved in biomimicry. Their responses indicated a wide range of fields, including "engineering (f=15)," "biology (f=11)," "multiple disciplines (f=9)," "physics (f=8)," "architecture (f=6)," "medicine/pharmacy (f=6)," "mathematics (f=6)," "science (f=4)," "design (f=4)," "aerospace (f=4)," "chemistry (f=2),"

"art (f=2)," "fashion (f=2)," "technology (f=2)," "STEM (f=2)," and other related fields (f=6).

Notably, Teacher 8 commented, "It has started to be used in education," indicating a relatively recent expansion of biomimicry into the educational field, though this perspective was only mentioned by one participant.

3.2. The Use of Biomimicry in Classroom Instruction

For the second sub-problem, teachers were asked a main question regarding whether they incorporate biomimicry into their lessons, and if so, how they implement this concept through activities, projects, or exercises. Upon analyzing the responses, it was found that 10 teachers answered "Yes," while 9 teachers responded "No." Among those who responded affirmatively, four teachers specifically noted that they integrate biomimicry into their project work.

A closer examination of the responses from the teachers who answered "Yes" revealed that some educators engage their students in hands-on, practical activities related to biomimicry, while others, despite not conducting dedicated classroom activities due to the lack of explicit curriculum content, use the concept as supportive examples to aid understanding.

Conversely, the responses from teachers who answered "No" indicated that their lack of use of biomimicry in lessons is primarily due to the absence of this concept in the curriculum. This issue was particularly noted by biology teachers, who expressed that the pressure to prepare students for university entrance exams often leaves little time for incorporating biomimicry-related activities.

Those who indicated using biomimicry in their projects explained that they primarily incorporate it within the context of national and international competitions, such as TÜBİTAK (The Scientific and Technological Research Council of Turkey) and TEKNOFEST, where they encourage students to develop innovative designs and propose practical solutions inspired by biomimicry.

From this analysis, it can be inferred that science teachers tend to incorporate biomimicry more frequently than biology teachers, likely due to a broader thematic overlap in their curricula.

As a follow-up, teachers who responded "Yes" were asked to provide specific examples of the activities they use in their lessons. These responses were categorized into two main groups: "animals" and "plants." It was observed that teachers use biomimicry examples not only to illustrate scientific concepts but also to inspire project work, offer problem-solving strategies, and guide students toward developing sustainable designs for long-term human needs.

3.3. Reasons for Using the Biomimicry Concept

For the third sub-problem, teachers who reported using the biomimicry concept in their lessons were asked to explain why they choose to incorporate it. The responses were categorized into four main themes: reinforcing course content, project development, fostering environmental awareness, and supporting workshop activities.

Teachers indicated that they use biomimicry in various contexts, such as during topic transitions, when responding to student questions, providing real-life examples, or as part of direct instruction. Several responses highlighted project development and encouraging environmental awareness as particularly prominent reasons for using biomimicry in their teaching.

For example, Teacher 1 shared, "We used biomimicry within the scope of a project for mathematical modeling. In the STEM projects created by students, biomimicry was utilized not just for visual inspiration but also for functional design. For instance, we designed a house inspired by the way a sunflower orients itself, creating a structure that follows the sun for optimal solar energy capture."

Similarly, Teacher 19 noted, "I try to include it when discussing current topics so that students can become biologically literate, environmentally conscious individuals with a broadened perspective on their surroundings," emphasizing the role of biomimicry in promoting environmental awareness and shaping students into more environmentally responsible citizens.

3.4. The Contribution of Biomimicry to Classroom Instruction

To address the fourth sub-problem, teachers were asked several questions to identify the potential benefits of using biomimicry in their lessons. The first question was, "Do you believe biomimicry contributes to biology education?" In response, 16 teachers answered "Yes," while 3 teachers responded "No."

For instance, Teacher 6 expressed a more reserved stance, stating, "When I consider the areas where biomimicry is applied, it doesn't seem to provide a significant contribution to biology education specifically, though it might benefit other fields." Similarly, Teacher 3 noted, "Rather than directly contributing to biology, I believe it supports other fields through the foundational principles of biology," suggesting that the influence of biomimicry extends beyond the boundaries of biological sciences.

Teachers who agreed that biomimicry contributes to biology education were then asked, "If so, how?" The responses were grouped into four main categories: contributions to science and technology, contributions to material and project

design, contributions to understanding nature and living organisms, and contributions as a teaching tool.

For example, Teacher 9 emphasized the role of biomimicry in scientific innovation, stating, "I believe it is important for designing, developing, and perhaps finding solutions to problems by observing living things on Earth." Meanwhile, Teacher 1 highlighted the importance of biomimicry in educational material design, noting, "In biology education, it can be a source of inspiration for designing materials and integrating technology into education through functional, technology-based models."

In the category of contributions to understanding nature and living organisms, teachers noted that biomimicry encourages students to better grasp the complexities of the natural world, including both living and non-living components, through their design projects and class discussions.

Under the contributions as a teaching tool category, teachers mentioned that biomimicry can play a motivational role in directing students toward biology as a field of study and supporting their learning across multiple disciplines. They also highlighted the interdisciplinary potential of biomimicry, noting that it allows for connections to be made between biology and other subjects like mathematics, ultimately enhancing students' overall scientific literacy.

To further explore the benefits of using biomimicry in the classroom, teachers were asked three additional questions: "What are the advantages of using biomimicry in your lessons?", "What cognitive, affective, and psychomotor gains do you observe from using biomimicry in your lessons?" and "Have you observed any changes in your students before and after incorporating biomimicry? Could you explain?"

Given that not all teachers use biomimicry in their lessons, the number of responses to these questions was limited. The responses were categorized into three main types of student gains: cognitive gains, affective gains, and psychomotor gains.

Cognitive Gains: This category included insights like shifting perspectives, raising awareness, enhancing lesson effectiveness, building foundational knowledge, connecting lessons to real life, and contributing to teacher development.

Affective Gains: Responses in this category emphasized increased student interest and enthusiasm, inspiration, and heightened curiosity and excitement.

Psychomotor Gains: This category included improvements in fine motor skills and observational abilities.

Overall, the interviews suggested that the use of biomimicry in lessons provides a range of cognitive, emotional, and practical benefits, reinforcing the value of interdisciplinary learning and hands-on educational approaches.

3.5. Challenges in Using Biomimicry in Classroom Instruction

To address the fifth sub-problem, teachers were asked, "What challenges do you encounter when using biomimicry in your lessons?" to identify the difficulties faced in integrating biomimicry into classroom teaching. The findings related to the challenges of using biomimicry in lessons are presented in the table below (Table 2).

Table 2. Findings regarding the difficulties encountered during the use of biomimicry in lessons.

Theme	Category	Reviews	*f*
Challenges in Using Biomimicry in the Classroom	Insufficient Material/Technological Facilities	Depending on the region where the institutions we work in are located, sometimes children at the socioeconomic level have insufficient technological infrastructure (T1). We had a financial difficulty (T10). Material costs are required for the projects to be carried out. Ergonomic materials are required. It is very difficult for children to access these materials. There are financial difficulties (T15).	4
	Children's Low Level of Readiness	I see that children in middle school have some difficulty in structure and function due to their age. They may have difficulties in comprehending (T8). I think that this subject may not be suitable for the age of children. It may be more appropriate for use in high school (T15).	3
	Inadequate Course Materials	Examples for biomimicry are insufficient and very limited in the books (T1). Not encountering too many examples (T6).	2
	Other	Since they are the last subjects, students do not take the subject seriously (T2).	2

The responses gathered from the teachers revealed three main categories of challenges related to the use of biomimicry in lessons: low student readiness levels, insufficient financial/technological resources, and inadequate teaching materials.

In this category, teachers highlighted that younger students or those with gaps in their prior knowledge often struggle to grasp the concept, definition, and purpose of biomimicry. As a result, students may produce designs or projects that deviate from the intended learning objectives. For example, Teacher 8 noted, "…They can struggle to grasp the concept. Some even try to create exact replicas of living organisms, which can be a disadvantage," emphasizing the challenge of aligning student understanding with the broader principles of biomimicry.

Similarly, Teacher 16 explained, "…Sometimes children aren't aware of the living organisms in nature because they haven't seen them before. We often have to individually show these to students before starting activities," indicating the need for preliminary instruction to bridge these knowledge gaps.

Many teachers expressed that financial and technological limitations pose significant obstacles to implementing biomimicry projects. For instance, Teacher 1 shared, "…When I mention a sunflower, a child might picture it, but if I had a smart board in the classroom, I could show a real-time video of its movement, helping them observe and understand the concept better. Unfortunately, the lack of technology in schools is a major barrier," highlighting the importance of visual aids and technological support in enhancing student understanding.

Teachers also noted that increased funding for such projects could lead to both a higher quantity and quality of student outputs. This category included challenges related to the absence of biomimicry content in textbooks and curricula. Teachers pointed out that the limited and often scattered nature of biomimicry examples in educational materials makes it difficult to fully integrate the concept into regular lessons.

3.6. Recommendations for the Use of Biomimicry in Education

In the final sub-problem of this study, teachers were asked to share their recommendations for incorporating biomimicry into their lessons. The responses were categorized into several main themes: integration into the curriculum, inclusion in lessons and topics, increasing teacher awareness and knowledge, project-based learning, interdisciplinary applications, and laboratory work.

A significant portion of the teachers recommended that biomimicry be included in the curriculum and textbooks. Many teachers mentioned that the lack of explicit biomimicry content in current textbooks and curricula makes it challenging to teach this concept effectively. For example, Teacher 6 stated, "It is not a well-known or widely included concept. It could be added to textbooks," emphasizing the need for dedicated biomimicry sections in educational materials.

Additionally, teachers noted that the limited presence of biomimicry in Ministry of National Education (MoNE) textbooks restricts students' opportunities to engage with this concept as a primary source, potentially limiting their understanding and application of biomimicry in real-world contexts. Teacher 8 highlighted this gap, stating, "Students outside BILSEM should also have the opportunity to learn about these concepts, incorporate them into their lives, and develop their awareness," reflecting the need for broader curriculum reform.

Inclusion in Lessons and Topics

Several teachers suggested incorporating biomimicry into existing lesson plans, either as standalone units or integrated into related topics like environmental science, technology, and design. For instance, Teacher 12 proposed, "It can be adapted to life-related topics. Experiments can be conducted, models can be made for practical application, and visual comparisons can be included in lessons," emphasizing the importance of hands-on learning and visual aids in teaching complex concepts like biomimicry.

Increasing Teacher Awareness and Knowledge

Teachers also recommended professional development programs to enhance their understanding of biomimicry, enabling them to serve as more effective guides for their students. This includes workshops, seminars, and training sessions aimed at improving teachers' knowledge and confidence in teaching this interdisciplinary concept.

Project-Based Learning

Many responses highlighted the importance of incorporating project-based learning (PBL) to engage students in real-world problem-solving. Teachers suggested that biomimicry-themed projects, like those included in STEM and engineering sections of science textbooks, could foster critical thinking and creativity. This approach would also align with the broader goals of developing 21st-century skills, such as collaboration, innovation, and environmental awareness.

Interdisciplinary Applications

Given the interdisciplinary nature of biomimicry, several teachers emphasized its potential for integration into subjects beyond the natural sciences, including mathematics, art, and technology. They noted that encouraging students to explore connections between different fields can lead to more innovative and holistic learning experiences.

Laboratory Work

Finally, teachers suggested the inclusion of biomimicry in laboratory work, providing students with hands-on opportunities to experiment with biomimetic designs and applications. This approach, they argued, would make lessons more engaging and meaningful, helping students better understand the principles of biomimicry through direct observation and practice.

Overall, the responses indicate that teachers view biomimicry as a valuable educational tool with the potential to enhance student learning across multiple disciplines, provided that appropriate curriculum adjustments, teacher training, and resource support are implemented.

4. Discussion and Conclusion

In this study, biology and science teachers' views on biomimicry were investigated. The results obtained are listed as; "teachers have a good command of the concept of biomimicry, but some teachers have concept confusion, they use biomimicry for various purposes in their lessons, biomimicry provides multifaceted contributions to lessons and students, teachers encounter various difficulties during the studies, and suggestions that biomimicry should be included in textbooks, course curriculum, printed and digital resources, teacher trainings, and student workshops".

In the interviews conducted within the scope of this study, it was observed that science teachers included the concept of biomimicry in their lessons more than biology teachers. Based on the teachers' opinions, the reason for this situation is that the subjects in the science curriculum include subjects that allow the use of the concept of biomimicry. In the biology curriculum, on the other hand, this concept is included in only one reading passage. In addition, teachers working at the secondary education level, especially science high school teachers, stated that they prepare their students for central exams and plan their lesson hours to include these studies. For this reason, it was seen that they had difficulties in including current issues such as the concept of biomimicry in their lessons. It was concluded that teachers working in primary and secondary BİLSEMs were able to carry out more studies on the concept of biomimicry due to the curriculum compared to teachers working in other school types.

It was determined that all of the teachers with whom interviews were conducted knew the concept of biomimicry, but teachers who had a master's or doctorate degree, participated in seminars and various trainings had a higher command of the subject. This situation was also reflected in the analysis of the study and caused the opinions of some teachers to come to the fore.

During the interviews, it was realized that some teachers used the concepts of "biomimicry" and "mimicry" in the same sense and that they had a concept confusion in this regard. In the national 11th Grade Science High School Biology coursebook, mimicry is defined as "Mimicry is the phenomenon in which a species imitates the appearance, smell or sound of another species. Mimicry allows the species to protect itself from predators. Mimicry can be seen in both prey and predator species" (p. 261). However, biomimicry is defined as "people taking nature as an example to solve the problems they face" (TÜBİTAK Bilimgenç, 2023). As can be seen from the definitions, the concepts of mimicry and biomimicry are two different concepts in the literature. While mimicry is the imitation of another living creature by a living creature, biomimicry is the design of designs in a wide variety of fields that can solve existing problems by taking inspiration from living and non-living beings. During the interviews, it was observed that especially the teachers working in the biology branch used these two concepts as the same concepts. For this reason, they included explanations about mimicry in their definitions. T18 said, "Mimicry. We can define it as a species imitating similar characteristics of a close species." and T9 said There are different definitions about biomimicry. For example, imitating the behavior of an animal." are among the answers that support this situation.

In the results obtained in the study, it was seen that the teachers used the expressions "imitating ecosystems, living and non-living things to create new products or to offer solutions to problems" when defining the concept of biomimicry. Oguntona and Aigbavboa (2023) stated that by studying and imitating natural forms, strategies, processes and ecosystems, students can develop a deeper understanding of the world around them and apply this knowledge to create sustainable designs and solutions. Similarly, Yıldız (2023) observed that regarding the concept of biomimicry, students generally adopted the definitions of being inspired by nature or living things, imitating living things and being inspired by nature. It is seen that the data obtained in this study overlap with the studies on the definition of biomimicry.

In the data of the study, it was seen that science teachers (f=8) included the concept of biomimicry in their lessons or studies more than biology teachers (f=2). Biology teachers stated that they could not include this and similar studies due to the inadequacy of the curriculum and course programs both in terms of having studies on the subject and in terms of course hours, and the demands of the students to conduct studies for the university exam. Science teachers, on the other hand, stated that they used the concept to support the subject with examples within the scope of "engineering skills" studies and "Force and Motion, Sound Properties" units within the scope of the course curriculum. Similarly, Çakır (2019) found that pre-service biology teachers were often inspired by natural events to demonstrate curriculum outcomes, but their understanding of the concept of biomimicry was relatively weak. In the study, it was observed that teachers who included biomimicry in their lessons stated that they guided their students to make designs inspired by insects, plants and bats and gave examples to their students. In the study conducted by Yakışan and Velioğlu (2019) with 4th grade students, it was observed that students were inspired by animals such as turtles, frogs, whales, fish, insects, giraffes, snakes, sea turtles, rabbits, owls, bats, birds, and cheetahs to create designs and drawings related to these designs. Savran Gencer et al. (2020) planned an engineering design process that allows students to imitate the structure,

function and tasks of living and non-living things. In the study, students made designs inspired by pelicans, geckos, flycatcher plants, bats, hawks and chickens and explained which problem their designs would solve. Ergül (2023) included organisms such as the flexible arms of octopus, potter's bird, spider web, sunflower, chrysanthemum, etc. to exemplify biomimicry in his study and mentioned both the structural and functional dimensions of the organisms presented as examples.

Stating that they introduced biomimicry to their students through workshops and offered them the opportunity to make designs, teachers stated that they carried out studies at the point of integrating biomimicry and education. In addition, teachers stated that they use biomimicry in their lessons, projects and in raising students' awareness of nature. Similarly, Oguntona and Aigbavboa (2023) stated that biomimicry concepts can be integrated into education through courses and workshops. In this context, the study is similar in terms of the implementation of the theoretical suggestion. Yıldırım (2019) stated that pre-service teachers wanted to include biomimicry practices in their courses and that they thought to use biomimicry practices in their courses under the titles of teaching-learning processes, teaching principles and scientific process skills. The pre-service teachers stated that they would use biomimicry applications for teaching from concrete to abstract within the scope of teaching principles; for observation and data recording within the scope of scientific process skills; and for active learning and learning through play within the scope of teaching-learning processes. In this context, although pre-service teachers expressed the reasons why they wanted to include biomimicry in their lessons as gaining 21st century skills, facilitating the understanding of the course by integrating it into teaching principles that respond to the needs of students, and using methods in which students will take an active role in learning-teaching processes, the teachers in the study stated where they used biomimicry. In the light of the findings obtained in the study, it was seen that the results differed from the data in the literature in terms of the reasons for the use of biomimicry.

In the study, it was observed that teachers who included biomimicry applications and activities in their lessons or projects expressed the positive contribution of biomimicry in supporting the cognitive, affective and psycho-motor multidimensional development of their students after the activities. When the literature was examined, studies conducted with pre-service teachers and secondary school students who continue their education at the faculty of education were found. In these studies, it was stated that within the framework of the concept of biomimicry, significant contributions were made to students in terms of cognitive, metacognitive, affective and psychomotor aspects. Yıldırım (2019) stated that including biomimicry applications in STEM education benefits the cognitive and psychomotor development of prospective teachers. Adıgüzel et al. (2024) emphasized that the contribution of the biomimicry approach is important in supporting the development of metacognitive and affective features among the curriculum objectives. They emphasized that developing the biomimicry approach and integrating it with education through different disciplines supports students' metacognitive skills and affective characteristics. In this context, the study coincides with the results emphasized in the literature.

In this study, teachers stated that when they included biomimicry applications or examples in their lessons, their students' motivation, enthusiasm, interest and curiosity increased; it made the lessons more enjoyable and guided them to gain new perspectives by sensitizing them. In the interviews with the teachers, it was stated that the teachers who used biomimicry in their lessons observed cognitive, affective and psychomotor developments in their students, and that they were supported to become more conscious, respectful to nature, able to look at their environment with different eyes, enthusiastic, curious and knowledgeable individuals in daily life. When the information in the literature and the results obtained from the analysis are examined, it is seen that our study is similar to previous studies. Similarly, Hu (2023) emphasizes that biomimicry aims to develop students' creative skills, enhance their curiosity and motivation, increase their achievement and self-confidence through hands-on learning experiences, promote peer interaction through collaborative teamwork, and encourage them to explore their own interests and expertise through various hands-on tasks.

Oguntona and Aigbavboa (2023) stated that biomimicry often begins with a sense of curiosity. They stated that educators can encourage a sense of awe and curiosity in their students by organizing activities such as outdoor learning experiences, nature walks and observation exercises. Mirici et al. (2021) stated in their study that practices in which biomimicry is integrated into education have a positive effect on students' motivation as they enrich the educational environment. In particular, he stated that the activities included in the classroom facilitate students' learning in different areas, increase their interest and contribute greatly to making the lessons fun. In addition, Oguntona and Aigbavboa (2023) stated that biomimicry is an effective field in gaining skills such as respect for nature, developing a different perspective on the natural environment, associating learned knowledge with real life, critical thinking and problem solving, and developing students in a multifaceted way. Yıldırım (2019) stated that pre-service teachers stated that biomimicry applications contributed to awareness, hand-eye coordination and gaining a different perspective. B. Aydın (2023) stated that biomimicry activities made science lessons more fun and exciting and increased their interest in lessons and school, a topic frequently emphasized by students in their interviews. In addition, D. Aydın (2023) stated in the observations made within the scope of the study that these activities improved students' awareness of nature, environment and sustainability. Similarly, studies conducted with

prospective biology and science teachers on nature, environment, and sustainability have also been found to contribute to the development of their awareness (Köklükaya & Yıldırım, 2016; Selvi et al., 2018; Uzel, 2019; Yiğit et al., 2022; Yildirim et al., 2022). In his study, Stevens (2021) stated that making nature-inspired designs arouses a sense of happiness in students, increases their curiosity and encourages their desire for continuous learning. He also emphasized that it increased students' interest in sustainable solutions.

Textbooks and the internet are the primary sources of information. Therefore, it is important for students and educators that resources are rich in information and examples. In this study, the lack of sufficient information and examples on biomimicry in the sources and the limited written resources were among the difficulties encountered. When the literature is examined, Oguntona and Aigbavboa (2023) reached similar conclusions by stating that there are insufficient resources and difficulties in accessing relevant information, so it will be difficult to integrate biomimicry into the curriculum. Dilaver Türe (2023) stated that the integration of STEM studies involving biomimicry activities into the teaching process is incompatible with the curriculum and syllabi, concerns arising from the preparation process for the university entrance exam and the time factor are among the difficulties experienced. The difficulties in the literature and the findings in this study are similar.

In the interviews with the teachers, it was seen that students had difficulty in understanding the philosophy of biomimicry due to the differences in their level of readiness while making biomimicry designs and projects on this subject, and for this reason, students stated that they tried to make a living model directly instead of being inspired by the characteristics of living things. Stevens (2021) stated that during biomimicry applications, students had difficulty in translating biological mechanisms into biomimicry designs. Similarly, Alperen (2020), during his study with 5th grade students, found that although he showed many examples of biomimicry to the students, they could not gain an understanding of biomimicry due to their age group. In this context, it is seen that the difficulties encountered in the studies in the literature are similar.

As a result of the analyses, it was seen that teachers' views on the inclusion of biomimicry in the curriculum and textbooks came to the fore. When the national and international literature was examined, it was seen that there are many suggestions for including biomimicry in the curriculum. Similarly, Staples (2005) emphasized that integrating the concept of biomimicry into the environmental education curriculum is important for two main reasons. The first one is to convey that there is hope in solving environmental problems. The second is to understand the importance of education for a sustainable future. In particular, the integration of biomimicry into the environmental education program in the high school curriculum is seen by Staples (2005) as an important material for the learning environment and a good example for the problem-based learning approach. In addition, Arslan Selçuk and Mutlu Avinç (2022) stated in their study that it would be useful to develop a course on "bio-informed design in architecture" in the architectural education curriculum beyond the elective course of bio-inspired design approach and emphasized the importance of including the subject in the curriculum. Barnes (2007) stated that education is the key to the spread of biomimicry and that biomimicry should be included in the curricula so that individuals can become aware of this concept. Çoban and Coştu (2023) stated that the more organisms students meet, the more creative ideas they can produce. The richer we keep the books, which are one of the main ways for students to obtain information, in terms of examples and information, the easier it will be for individuals to meet and work with such concepts. For this reason, curricula, books and computer-aided technological applications should be enriched and include current issues. Again, Savran Gencer et al. (2020) emphasized that it is important to include biomimicry in the science curriculum because it allows the integration of the STEM concept with the classroom environment. According to the researchers, introducing the concept of biomimicry to children during STEM education will provide an opportunity to connect nature with engineering, technology, mathematics, and science.

It is important that teachers, who act as a bridge between knowledge and students, become well-equipped, researcher individuals who follow current scientific knowledge and transfer it to their students. The results obtained in this study emphasize the suggestions for organizing workshops and laboratories in cooperation with universities and encouraging teachers to participate in these activities. Teachers stated that such trainings would be beneficial for their personal development. When the literature was examined, it was seen that there were studies that drew attention to this issue. Ergül (2023) stated that in order for the biomimicry approach to be adopted and used in schools, teachers should be supported with undergraduate education or in-service training such as skill-oriented training workshops. Dilaver Türe (2023) stated that extra in-service trainings should be organized for teachers for reverse engineering and biomimicry applications. He also emphasized the need for students to get to know living things, especially in order to be able to make biomimicry applications. Similarly, Ergül (2023) stated that interactive workshops held in science centers can be turned into more comprehensive studies with the support of universities and non-governmental organizations. D. Aydın (2023), on the other hand, found that students' inability to design products inspired by nature was due to the deficiencies of teachers who would guide them in this regard.

In the interviews, teachers suggested that biomimicry-based applications can be made to students in lessons, out-of-school learning environments, projects, laboratory environment and engineering skills. They also thought that its use in education would inspire students to make designs inspired by nature. When the literature was analyzed, similar results were found. Oguntona and Aigbavboa (2023) stated that students can develop innovative solutions to engineering and design challenges by examining and imitating biomimetic materials; biomimicry can inspire students to create more sustainable and efficient solutions or technologies by integrating biomimicry into STEM education. Mirici et al. (2021) stated that it is extremely important to enrich the teaching environment by including studies that encourage students to research, produce and invent, and reveal their abilities and interests in these subjects. Similarly, Çoban and Coştu (2023) stated that biomimicry can be effective in field observations in nature, exploring organisms with educational materials such as microscopes and magnifying glasses, and creating more different design ideas. Ergül (2023) stated that due to the nature of biomimicry, it would be useful to observe the creature to be inspired in its natural environment and emphasized the necessity for children to make observations, discoveries and activities in open spaces, in nature.

In the interviews, teachers emphasized the need to include biomimicry not only in biology or science but also in different disciplines. In addition, teachers stated that studies should be carried out to increase awareness and knowledge levels. When the literature on these suggestions is examined, B. Aydın (2023) stated that biomimicry can be applied not only in science courses but also in other courses such as mathematics and Turkish. Similarly, Staples (2005) stated in his study that biomimicry has a high potential to be integrated into many disciplines and many levels of education. The researcher also drew attention to the interdisciplinary nature of biomimicry by stating that projects can be developed in elementary school years on a basic exploration of nature, in high school in environmental science, biology and art courses, and in fields such as architecture and design. In addition, Oguntona and Aigbavboa (2023) stated that it would be difficult to realize an effective adaptation of biomimicry to the curriculum without educators having sufficient knowledge and skills in biomimicry. Similarly, Arslan Selçuk and Mutlu Avinç (2022) emphasized the importance of the personal development of people interested in architectural education by stating that it is extremely important for them to follow the technological and scientific developments of the age, to adopt sustainable methods and strategies integrated with nature, and to be aware of the potential that nature can offer them.

4.1. Recommendations

It is recommended that biomimicry applications and similar topics be included in the curriculum and textbooks. For this purpose, curricula, textbooks and course hours should be organized accordingly. Teacher training programs should include more information about biomimicry. Teacher trainings, seminars and workshops can be encouraged. In future studies, teachers can be informed about the subject and participate in application studies. Interviews before and after the training can be conducted to contribute to the literature on the subject. The scope of the study can be expanded to include different provinces or even the whole of Turkey, and quantitative studies can be conducted with a large sample of biology and science teachers. Future research could include interviews with teachers from different branches and school types to make comparisons.

Compliance with Ethical Standards

The study protocol was approved by Gazi University Ethics Committee with the decision number E898063 on 06.03.2024.

Conflict of Interest

The authors have no conflict of interest to declare.

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