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AN EXAMINATION OF SCIENCE TEACHERS' AWARENESS OF BIOMIMICRY AND STEM

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Abstract:
In this study, it was aimed to examine science teachers' awareness of biomimicry and STEM, and to evaluate their awareness levels in terms of variables such as gender, years of experience, STEM training status, and school type. The study was conducted using the survey model and the causal-comparative model, which are among the quantitative research methods. The sample of the research consisted of 153 science teachers working in the province of Adıyaman during the 2022–2023 academic year. The data collection tools used in the study were the Biomimicry Awareness Questionnaire and the STEM (FeTeMM) Awareness Scale for Secondary Education Teachers. According to the results, it was determined that science teachers had a basic level of awareness regarding the concept of biomimicry; however, their in-depth knowledge and practical experience related to the concept were limited. The teachers' general attitudes toward the STEM approach were found to be positive. It was found that STEM awareness levels did not differ significantly according to gender, years of seniority, STEM training status, or type of school in which the participants worked. Additionally, it was concluded that the type of school in which teachers worked did not have a significant effect on STEM awareness. Based on the findings of the research, several recommendations were made to enhance teachers' awareness and competencies regarding biomimicry and STEM practices.

Keywords: biomimicry; STEM; science education; science teachers

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1. Introduction

Since its existence, humanity has been in continuous interaction with nature in order to produce practical solutions to ecological and structural problems. However, conventional production models and technological advances that gained momentum particularly after the Industrial Revolution have made humanity dependent on non-renewable energy sources. The exploitation of natural resources through a linear logic and the toxic wastes released into the environment threaten the balance of the global ecosystem in an irreversible way. Today, deepening ecological crises make it necessary to turn to environmentally friendly, innovative approaches compatible with the laws by which nature operates in order to build a sustainable future. When the historical course of the human-nature relationship is considered, it is seen that human beings initially tried to understand and observe nature, but over time fell into the illusion of dominating nature through a palette of technological power (Benyus, 2002).

One of the most concrete and innovative methodologies developed against these crises in the modern world is biomimicry. Biomimicry is an interdisciplinary approach that aims to seek sustainable solutions to human-generated problems by examining the biological structures, forms, and systems that living organisms have developed to adapt to changing environmental conditions during billions of years of evolution (Benyus, 2002). The philosophy of viewing nature as a model, measure, and mentor is based on a tradition whose roots extend deep into human history. Indeed, Leonardo da Vinci's development of early flying-machine designs by studying the flight anatomy and aerodynamics of birds is one of the most qualified historical references for this approach (Marshall, 2009). Today, functional designs produced by imitating biological mechanisms in many disciplines, especially engineering, architecture, and industrial product design, demonstrate the strategic and innovative value of this methodology in the contemporary world (Volstad & Boks, 2012).

In the twenty-first century, the wave of globalization and the dazzling pace of digital transformation make it necessary to restructure educational paradigms and integrate multidimensional approaches into classroom environments (Arhin & Laryea, 2018). In this context, STEM education (Science, Technology, Engineering, and Mathematics) comes to the fore. By addressing these four basic disciplines through an integrated philosophy, STEM enables students to use their theoretical knowledge in solving real-life problems (Bybee, 2014; Funa, 2026). Although biomimicry and STEM are sometimes confused conceptually, the focal points of the two approaches differ: biomimicry focuses directly on the process of modelling hidden engineering and designs in nature, whereas STEM provides this modelling and solution-generating action with a systematic, planned, and pedagogical instructional framework (Han & Shim, 2019). Integrating biomimicry into science education by supporting it with STEM-based strategies transfers learning from nature to an interdisciplinary, applied, and production-oriented ground (Benyus, 2002).

While nature is a design laboratory that has produced the most excellent forms through an evolutionary trial-and-error filter, STEM is a functional vehicle that transfers this magnificent engineering accumulation into modern classrooms (Gavrilas & Kotsis, 2025). Contemporary educational understanding and process-oriented curricula such as the Turkish Century Education Model expect students to blend the outcomes they acquire with high-level twenty-first-century skills such as critical thinking, creative problem solving, and innovation (Trilling & Fadel, 2009). In this direction, science education has a locomotive role in enabling individuals to make sense of the environment and acquire scientific literacy (Mingoa, & Abocejo, 2021; Guerrero & Sjöström, 2025). Science teaching, which incorporates the processes of analytical observation and establishing causal relationships, has an organic connection with biomimicry due to its ontological structure that centers on nature (Adiguzel *et al.*, 2024). Considering technological leaps nourished by the intersection of science, mathematics, and engineering (Salman-Parlakay, 2017), it is clear how critical a role science education plays in constructing a sustainable technology and innovation ecosystem (Onoshakpokaiye & Avwiri, 2025).

Changes in social and technological needs require periodic revision of educational policies and curricula (Law, 2022; Cerezo *et al.*, 2023). Science curricula in Türkiye have also been updated throughout history to educate scientifically literate and productive individuals in line with the spirit of the age (Bilir, 2025). In this direction, STEM philosophy has found broad coverage in recent curricula, and an intensive body of studies has emerged in the literature. Nevertheless, it is observed that pedagogical research on biomimicry, which aims to carry the sustainable genius of nature into education, has remained quite limited (Avci, 2019; Hocaoğlu & Coştu, 2026). Yet biomimicry, as an approach that envisions producing environmentally friendly solutions by taking natural designs as a guide, has very high potential for triggering students' creativity and design-oriented thinking skills (Vasinayanuwatana & Plianram, 2023).

The permanent and effective realization of innovative educational approaches in classroom environments is undoubtedly directly related to the professional competence and awareness levels of teachers, who are the implementers of the process (Kozikoğlu, 2025). A qualified science teacher should be able to motivate students at a high level, possess intellectual mastery of curricular content, create a climate of creative thinking, and benefit from rich material diversity in instruction (Mastul, 2024). Current literature in teacher education also aims to equip teachers with such innovative pedagogical skills and to support the visionary teacher profile needed by the education system (Villegas Reimers, 2003; Caena & Redecker, 2019). Blending the biomimicry methodology with STEM-oriented practices fits perfectly with the constructivist nature of science education; it both sharpens students' scientific process skills and instills environmental awareness (Magana,2026). At this point, science teachers' perceptions and awareness of STEM and biomimicry approaches emerge as a key factor in designing lessons that are student-centered, practice-oriented, and far from rote learning.

2. Literature Review

The earth, as a living and complex macro-system, has maintained its dynamism thanks to the principles of balance, adaptation, and resource efficiency that it has developed over an evolutionary filter of approximately 3.8 billion years. Following the ecological damage caused by the industrial age, humanity has tended to move away from the mistake of seeing nature merely as a passive storehouse of raw materials and has developed new paradigms focused on understanding the genius embedded in its functioning. Biomimicry, located at the center of this search, is an interdisciplinary methodology that aims to empirically examine the structures, processes, and survival strategies operating in nature at micro and macro levels and transfer them to disciplines such as technology, architecture, engineering, and industrial design (Benyus, 2002). Studying nature is not merely an observational activity; it also opens the door to innovative learning processes compatible with ecological sustainability.

Although different formulations such as bio-inspiration, biophilia, biomimetics, bionics, and bio-utilization appear in the international literature, biomimicry differs from other approaches through its philosophy of learning and understanding nature's structural principles rather than simply making formal imitations to reach functional designs. The concept gained a global identity through Benyus's (2002) pioneering work. Benyus describes biomimicry as the transfer of models, processes, and systems in nature through emulation in order to create designs compatible with ecological balances, and positions nature as a holistic mentor. Etymologically, the term derives from the Greek words bios (life) and mimesis (imitation/emulation). The common denominator of current definitions in the literature (Fisch, 2017) is that biomimicry is not a shallow act of copying; rather, it is an in-depth thinking model involving the analysis, interpretation, and transformation into green innovations of systems optimized by nature in its evolutionary laboratory.

In an educational context, biomimicry is a contemporary pedagogical approach that aims to develop students' higher-order cognitive process skills. The fact that unsuccessful designs were eliminated during evolution while highly efficient systems survived proves that nature is a vast R&D laboratory (Benyus, 2002). Therefore, the assumption that a technical or environmental obstacle encountered has probably already been solved in nature provides students with an innovative perspective and organizes their ability for design thinking (Kandemir *et al.*, 2022). Anatomical forms and adaptation strategies of living organisms feed many fields, from engineering to materials science. Today, this interaction has been institutionalized by leading centers such as the Biomimicry Center at Arizona State University and Harvard University's Wyss Institute. Dawson and Winks (2021) argue that these nature-centered learning models can be flexibly adapted to existing school curricula without adding an extra burden and that they support affective learning outcomes.

Janine Benyus (1997) establishes the philosophical and operational tripod of biomimicry on three main axes:

- **Nature as model:** It offers structural solutions such as photovoltaic cells inspired by leaves or smart solar panels imitating sunflowers (Tezel Ersanlı & Ersanlı, 2023).
- **Nature as measure:** It involves questioning developed designs according to nature's ethical standards in terms of sustainability and ecological suitability (Dicks, 2017).
- **Nature as mentor:** It replaces the question 'What can we extract from nature?' with the paradigm 'What can we learn from nature?' (McGregor, 2013).

The Biomimicry Design Spiral, developed so that designers can put this philosophy into practice, is a cyclical, trial-and-error model comprising five mutually reinforcing stages: define, transform, discover, emulate, and evaluate (Kuday, 2009). Empirical iconic examples of transferring mechanisms in nature to technology include self-cleaning paints inspired by the hydrophobic surface of the lotus plant (Barthlott & Neinhuis, 1997), Velcro tapes invented from burdock hooks, the passive ventilation system of the Eastgate Shopping Centre modelled on termite mounds, and wind-turbine blades inspired by the tubercles on humpback whale fins (Fish *et al.*, 2011).

In the globalizing world economy, countries need qualified intellectual capital equipped with higher-order cognitive skills in order to achieve sustainable development momentum. Accordingly, STEM education, which provides an integrated teaching philosophy by dissolving the rigid boundaries of science, technology, engineering, and mathematics disciplines, stands out as a strategic reform model. Rooted in the search for interdisciplinary integration in the 1990s (Bybee, 2010), this approach aims to help students concretize theoretical knowledge through every day-life problem rather than leaving it within abstract patterns (Gonzalez & Kuenzi, 2012). In this respect, the approach is a modern projection of John Dewey's educational philosophy of learning by doing and experiencing (Çorlu *et al.*, 2014).

STEM education has two main macro goals. The first is to expand the pool of innovative human resources who will choose STEM fields as careers at the industrial level; the second is to raise the level of scientific literacy in society by improving analytical thinking and problem-solving abilities (Sanders, 2009). This pedagogy, which is a key to national development, has also found a place in Türkiye under the abbreviation FeTeMM and has been accepted as a cornerstone in building an education model focused on entrepreneurship, innovation, and production (Arslan& Arastaman, 2021). The most prominent actor in achieving sustainable success for this transformation in classroom settings is undoubtedly the teacher. It is not enough for teachers to possess only subject-matter knowledge in their own branches; they must also possess pedagogical content knowledge that enables them to blend this knowledge with engineering design processes (Bybee, 2013). In science classrooms enriched with design-oriented activities, students' motivation toward school and science has been found to be significantly higher than in traditional classrooms (Tanış Özçelik& Akkor, 2026).

When educational policies in Türkiye are examined, it is seen that the strategic reports and national macro plans published by the Ministry of National Education make strong references to STEM and twenty-first-century skills (Ministry of National

Education, 2024). At the international level, industry-supported projects such as MASCIL (European Commission, 2015) and INSTEM, in which Türkiye also participated, have been carried out to increase teacher competencies. Parallel to this tendency in practice, empirical studies aimed at identifying teachers' STEM perceptions have also gained momentum in the national literature (Eroglu & Bektas, 2016; Boynukara *et al.*, 2020). Recent studies have also examined teachers' perceptions of interdisciplinary approaches, the challenges they face regarding material/time constraints, and the positive effects of STEM on creative design competencies (Özkaya *et al.*, 2022; Akça & Beşoluk, 2023). International systematic reviews and empirical studies (Margot & Kettler, 2019; Permanasari *et al.*, 2021) also report that teachers have positive attitudes toward STEM but encounter systemic barriers such as lack of pedagogical support and curriculum intensity.

The dynamic structure of the knowledge society demands that educational processes raise generations who inquire, think in systems, and are in harmony with the laws of nature (Avci, 2019). This requirement has led to the idea of strategically blending the philosophy of biomimicry with STEM pedagogy in science education. At the international level, the Bio Learn Project conducted by the Biomimicry NL consortium aims to prove the role of nature-inspired innovation by providing STEM teachers with biomimicry-focused material support. Current curricula also envision creating interdisciplinary environmental and ecosystem awareness by placing science, technology, engineering, and design skills at the center of science education.

While STEM education focuses on academic goals through the engineering design cycle, biomimicry places nature's sustainable genius and ecological sensitivity at the center of this cycle. When these two approaches are integrated, students gain ecological literacy by searching for solutions in nature's billions of years of optimized templates. The unit 'Technologies Inspired by Nature' in the Ministry of National Education's Science Applications Course Curriculum (Ministry of National Education, 2018) is the most concrete basis for this integration in the official curriculum. Global authorities such as the Next Generation Science Standards (NGSS) and the National Science Teaching Association (NSTA) have also published pedagogical guides on positioning biomimicry in science classrooms (Bybee, 2014). For example, modeling the aerodynamic structure of an owl and applying it to Shinkansen high-speed trains (Nakatsu, 2005) is an excellent instructional material showing how biology, physics, and engineering can come together in science classrooms (Islam *et al.*, 2025). The blending of biomimicry, STEM, and design thinking becomes an eco-innovative pedagogical tool in the hands of teachers (Kaya, 2022).

When evaluated through a collective projection, the theoretical framework and related studies confirm that the integration of biomimicry and STEM provides tremendous cognitive and affective gains across a wide educational spectrum from preschool to higher education. Bringing nature into classrooms as a model, measure, and guide strengthens students' creative thinking, analytical data-reading, and environmental literacy skills.

However, it is noteworthy that a large portion of the existing studies in the literature is limited to narrow samples, student groups compressed into short time spans, or pre-service teachers. This situation proves the existence of a serious research gap regarding how the biomimicry philosophy can be integrated into official science curricula and real classroom ecosystems in a more systematic and sustainable manner. Most importantly, the extremely limited number of correlational studies that holistically examine the pedagogical competencies, readiness levels for biomimicry, and perceptions of STEM integration of in-service science teachers who will shoulder this process in the classroom constitutes the main rationale for the original contribution and academic value of the present study.

When national and international literature is evaluated, it is determined that although much data are available measuring science teachers' STEM awareness, studies examining biomimicry awareness or bringing these two modern approaches together under a single framework are extremely limited (Akgunduz *et al.*, 2015; Ozen, 2016). This academic gap makes visible the need for original studies that reveal how teachers make sense of biomimicry in their own educational practices and how they articulate this philosophy with STEM.

Based on this need, the main aim of the present study is to determine science teachers' awareness levels regarding STEM and biomimicry approaches. The study also examined from a multidimensional perspective whether teachers' awareness levels differ significantly in terms of various demographic parameters such as gender, professional experience (seniority), type of school served (middle school/imam hatip middle school), and prior STEM training. The empirical data to be obtained from the study are expected to make an original and qualified contribution to updating pre-service and in-service teacher training programs in line with contemporary needs, developing innovative/sustainable instructional strategies in science education, and shaping future educational policies in the light of scientific evidence.

3. Material and Methods

In this study, survey and causal-comparative research designs, both of which are quantitative research methodologies, were employed. Survey models aim to describe a phenomenon, situation, or target group as it exists within its own conditions, without any intervention (Karasar, 2024). The causal-comparative design was preferred to reveal, through objective criteria, whether participants' demographic characteristics that developed outside researcher control (gender, professional seniority, school type, and prior STEM training) create significant differences in the dependent variables (STEM and biomimicry awareness scores). This integrated methodological infrastructure enabled the current awareness maps of teachers to be presented objectively through quantitative data and allowed comparisons between groups.

The target population of the study consists of science teachers working within the borders of Adiyaman province. The sample group comprises 153 science teachers selected from this population through a convenience sampling strategy and participating voluntarily in the study. Convenience sampling, frequently used in quantitative research, is a rational approach that enables data to be collected systematically from the most accessible and cooperative units when there are barriers to field access due to logistical, financial, and time constraints (Büyüközturk *et al.*, 2018). Frequency and percentage distributions of the participating teachers' demographic characteristics are presented in Table 1.

Table 1: Demographic Distributions of Participating Teachers

Variable	**Groups**	**N**	**%**
Gender	Female	83	54.2
	Male	70	45.8
Professional Seniority	1-10 Years	69	45.1
	11-20 Years	55	35.9
	21-30 Years	26	17.0
Receiving STEM Training	Yes	50	32.7
	No	98	64.1
Type of School Served	Middle School	117	76.5
	Imam Hatip Middle School	32	20.9
Total		**153**	**100.0**

When the distributions in Table 1 are examined, it is seen that 54.2% of the sample group (N = 83) consists of female teachers and 45.8% (N = 70) consists of male teachers. In terms of professional experience, nearly half of the participants (45.1%) are relatively young professionals with 1-10 years of seniority; they are followed by teachers with 11-20 years of experience (35.9%) and 21-30 years of experience (17.0%). Only 32.7% of the teachers (N = 50) stated that they had previously received formal STEM training, while the majority (64.1%) had not undergone such pedagogical training. In terms of institutional distribution, it is understood that a dominant proportion of teachers (76.5%) work in general public middle schools and 20.9% work in Imam Hatip middle schools.

The data collection process in the study consisted of a Personal Information Form prepared to determine participants' demographic characteristics and a combination of two different scales/questionnaires whose validity and reliability have been proven in the literature. To measure teachers' perceptions of nature-inspired designs, the Biomimicry Awareness Questionnaire developed by Cakir (2019) was used. Item analyses conducted during the scale development phase revealed that item discrimination indices were statistically highly significant ($p < 0.001$) and that the original form's Cronbach's Alpha internal consistency coefficient was 0.857 (Cakir, 2019). In the reliability analysis repeated on the data of the present study, the Cronbach's Alpha coefficient for the entire questionnaire was calculated as 0.938. Considering that values of 0.70 and above are accepted as sufficient for internal consistency in methodological literature (Buyukozturk *et al.*, 2018), the questionnaire provided a high level of data reliability within this study. In order to measure teachers' perceptions of integrated education, the 15-item FeTeMM Awareness Scale developed by Cevik (2017) was employed. Structured in a five-point Likert type (1 = Strongly Disagree; 5 = Strongly Agree), this scale consists of three subdimensions evaluating the educational reflections of STEM education on students, lessons, and teachers. The overall Cronbach's Alpha coefficient reported as 0.82 by Cevik (2017) for the original form was calculated as alpha = 0.767 for the current sample of this study. Internal consistency values for the subdimensions were found to be 0.81, 0.71, and 0.70, respectively. These psychometric values confirm that the scale and its subcomponents are within empirically acceptable limits (George & Mallery, 2020).

As a result of the Pearson Product-Moment Correlation Analysis performed to determine the structural relationship between the measurement tools, a moderate, positive, and statistically highly significant correlation was found between teachers' biomimicry awareness scores and STEM awareness scores ($r = 0.615$; $p = 0.001$). This empirical finding proves that the conceptual structures measured by the two independent scales contain a compatible synergy in teachers' mental schemas.

3.1 Data Analysis and Normality Assumptions

Before analyzing the quantitative data obtained, missing data and outlier checks were performed; then normality assumptions were tested to decide whether the analyses would be conducted using parametric or non-parametric tests. In examining normality, not a single criterion but both numerical (Kolmogorov-Smirnov, Shapiro-Wilk, skewness-kurtosis coefficients) and visual (Q-Q plots and histogram curves) statistical techniques were evaluated together (Buyukozturk *et al.*, 2018). The homogeneity of variances, which is the basic prerequisite for intergroup comparisons, was examined using Levene's Test. In difference analyses, in addition to statistical significance ($p < 0.05$), Cohen's d effect size coefficients were calculated to determine the practical value of differences between groups. According to Cohen's (1962) classification, 0.20-0.50 is interpreted as small, 0.50-0.80 as medium, and 0.80 and above as a large effect size. In interpreting scale means, the following intervals were used: 1.00-1.80 Strongly Disagree, 1.81-2.60 Disagree, 2.61-3.40 Undecided, 3.41-4.20 Agree, and 4.21-5.00 Strongly Agree. Detailed normality test results for the dependent variables are given in Table 2.

Table 2: Normality and Distribution Statistics for Dependent Variables

Dependent Variable	Mean	SD	Skewness	Kurtosis	K-S (p)	S-W (p)
STEM Total Score	3.84	0.46	-0.214	-0.118	0.063 (0.200)	0.988 (0.219)
Biomimicry Total Score	42.98	11.55	-0.532	-0.650	0.114 (0.012)	0.942 (0.003)

Note: *$p > 0.05$ indicates the boundary for a normal distribution.

When the data in Table 2 are analyzed, it is seen that STEM total awareness scores are greater than the 0.05 significance level in both Kolmogorov-Smirnov ($p = 0.200$) and Shapiro-Wilk ($p = 0.219$) tests, indicating a normal distribution. Although the K-S and S-W test results for biomimicry total awareness scores are statistically significant ($p < 0.05$), which appears to indicate deviation from normal distribution, it is known that these tests become overly sensitive in large samples ($N > 100$). Therefore, the skewness (0.532) and kurtosis (0.650) values of the relevant variable were examined, and these coefficients were found to be within the interval accepted as ideal for normal distribution (Tabachnick &

Fidell, 2013). As visual Q-Q plots and kurtosis values continued to support this situation, it was concluded that both data sets met the prerequisites for parametric analysis. Accordingly, parametric statistical methods such as independent samples t-test, one-way analysis of variance (ANOVA), and Pearson correlation analysis were used in the analysis of the data.

4. Results and Discussion

When the frequency and percentage distributions of the responses given by the participating science teachers to the items of the biomimicry questionnaire were examined, it was determined that a significant proportion of participants had not encountered this concept before. To the statement 'Have you ever encountered the concept of biomimicry?', 54.9% of the teachers answered 'no'. Similarly, the high rate of choosing the 'I have no idea' option in items related to the interdisciplinary application areas and scope of biomimicry indicates that teachers experience a conceptual lack of knowledge.

On the other hand, it is seen that teachers can intuitively make sense of the ontological connection and functional value of biomimicry with science education. Of the participants, 43.8% stated that biomimicry is an interdisciplinary approach that brings science together with designs in nature, and 49.7% stated that it can be used in problem solving and developing new technologies. In addition, the proportion of those who agreed that tools developed by drawing inspiration from nature make life easier was calculated as 74.5%; the proportion of those who thought that inspiration from nature contributes to science education was 76.5%; and the proportion of those who stated that the interaction of nature and technology in science education would bring forth new products was 74.5%. Approximately half of the teachers (51.0%) stated that biomimicry could make important contributions to science teaching through the examination of living and non-living systems. These findings show that even though teachers do not know biomimicry in depth, they have a highly positive tendency toward nature-based innovative approaches.

The descriptive results obtained from the STEM Awareness Scale used to determine teachers' perceptions of the integrated education approach are presented in Table 3.

Table 3: Descriptive Statistics for the STEM Awareness Scale and Its Subdimensions

Scale and Subdimensions	Number of Items	Mean	SD	Level
STEM Student Dimension	6	4.44	0.56	Strongly Agree
STEM Teacher Dimension	5	3.96	0.67	Agree
STEM Lesson Dimension	4	3.33	0.55	Undecided
General STEM Awareness	15	3.84	0.43	Agree

When Table 3 is examined, it is seen that science teachers' general STEM awareness levels are high (Mean = 3.84; SD = 0.43). When the subdimensions of the scale are evaluated, the highest mean was in the STEM Student dimension (Mean = 4.44; SD = 0.56), whereas the lowest mean appeared in the STEM Lesson dimension (Mean = 3.33; SD = 0.55). In the STEM Teacher dimension, responses were at the Agree level (Mean = 3.96; SD = 0.67). This table reveals that teachers have high awareness of STEM education's contribution to students' twenty-first-century skills and to their own professional roles; however, they experience hesitations and reservations regarding the integration of the approach into lesson processes, including time, materials, and curriculum intensity.

The results of the study revealed that although science teachers have positive and intuitive awareness of the concept of biomimicry, this awareness lacks conceptual and pedagogical depth. Participants accept biomimicry as an interdisciplinary tool inspired by nature and supporting problem-solving. However, when it comes to practice, integration with curricula, and methodological principles, their knowledge level remains limited. The high rate of 'I have no idea' responses in questionnaire items clearly supports this conceptual gap and lack of practical experience.

This finding is fully consistent with studies in the literature stating that teachers and pre-service teachers regard biomimicry as an innovative approach but feel insufficient at the point of implementation (Çoban & Coştu, 2023; Çelik & Özel, 2025). It is valuable that teachers welcome this theoretical structure based on learning from nature; yet the need for guidance on which learning outcomes and how this approach should be integrated into classroom practice indicates that biomimicry has not yet found sufficient place in teacher education and in-service training programs.

Whether teachers' general STEM awareness and subdimension scores differed by gender, years of seniority, prior STEM training, and school type was examined through parametric tests. According to independent samples t-test results, the general STEM awareness mean of female teachers (Mean = 3.95; SD = 0.42) appeared slightly higher than that of male teachers (Mean = 3.93; SD = 0.44), but this difference was not statistically significant ($p = 0.774$). In analyses at the subdimension level, no significant difference related to gender was found in the student ($p = 0.497$), lesson ($p = 0.745$), or teacher ($p = 0.857$) dimensions. The calculated Cohen's d value of 0.04 confirms that the difference between genders is negligible and that this variable is not a determinant of STEM awareness.

One-way analysis of variance (ANOVA) was applied to STEM awareness scores according to participants' professional experience. Before the analysis, the homogeneity of variances was confirmed by Levene's test ($p = 0.727$). ANOVA results showed that teachers' STEM awareness total scores did not differ statistically significantly by years of seniority ($p = 0.823$). Although the means of teachers with 1-10 years of seniority (Mean = 3.98; SD = 0.43) were arithmetically slightly higher than those with 11-20 years (Mean = 3.93; SD = 0.41) and 21-30 years (Mean = 3.94; SD = 0.47), this situation was not significant. The calculated effect size value (eta squared = 0.0026) indicates that the explanatory power of years of professional service on STEM perception is very weak.

Teachers who had previously received formal STEM training had higher general STEM awareness means (Mean = 4.06; SD = 0.39) than those who had not received training (Mean = 3.89; SD = 0.44). Similarly, in all student (Yes: Mean = 4.62 / No: Mean = 4.36), lesson (Yes: Mean = 3.44 / No: Mean = 3.29), and teacher (Yes: Mean = 4.01 / No: Mean =

3.94) subdimensions, the scores of those who received training were systematically higher. However, independent samples t-test analyses revealed that none of these arithmetic advantages indicated a statistically significant difference at the 0.05 level ($p > 0.05$).

The general STEM awareness scores of teachers working in middle schools (Mean = 3.95; SD = 0.43) and those working in Imam Hatip middle schools (Mean = 3.93; SD = 0.46) were very close to each other, and the difference was statistically nonsignificant ($p > 0.05$). No significant differentiation was found in the student ($p > 0.05$), lesson ($p > 0.05$), or teacher ($p > 0.05$) subdimensions by school type. This indicates that STEM awareness follows a developmental line independent of institutional school structure.

The high level of teachers' general STEM awareness can be interpreted as a reflection in the field of the importance given to STEM in educational policies. When examined dimensionally, the highest mean in the student dimension shows that teachers have a strong belief in the contribution of this approach to twenty-first-century skills such as problem solving, critical thinking, and creativity. This situation is parallel to common empirical findings in the literature.

By contrast, the relatively low mean in the lesson dimension is a critical finding. Teachers believe in the necessity of STEM in the teacher and student dimensions, but in practice they perceive chronic obstacles such as time insufficiency, lack of materials, and intensity of curricula.

When demographic variables were examined, no statistically significant difference was found in teachers' STEM awareness scores in terms of gender, professional seniority, school type (middle school / imam hatip middle school), or even prior STEM training.

There are studies in the literature that similarly found no significant differences by gender (Cevik *et al.*, 2017; Karakaya *et al.*, 2018) and seniority (Altun & Apaydın, 2022; Yaman & Aşılıoğlu, 2022). When evaluated together with studies reporting different results (Alğın Açıksöz & Esen Aygün, 2023; Taytak, 2024), it can be said that STEM awareness is shaped not by biological sex or length of professional service but by more complex and contextual factors such as openness to innovations, individual motivation, and qualified professional development opportunities.

Although teachers who received STEM training had arithmetically higher means, it is noteworthy that this did not reach statistical significance. This situation can be explained by the fact that the STEM concept has now gained structural popularity in the educational ecosystem through informal channels, academic publications, and current curriculum discussions. Teachers who have not received training also possess theoretical familiarity and awareness; however, this blurs the line between awareness and implementation competence.

In this section of the research, the effect of responses ('Yes', 'No', 'I have no idea') to specific items in the Biomimicry Awareness Questionnaire that were considered directly related to the science/technology context on teachers' general STEM awareness scores was examined using one-way analysis of variance (ANOVA). The findings are summarized in Table 4.

Table 4: ANOVA Results for STEM Awareness Scores by Responses to Selected Biomimicry Items

No.	Questionnaire Item	F	p
M3	Biomimicry combines science with designs in nature and creates a new discipline.	0.973	$p > 0.05$
M5	In the educational process, biomimicry aims to develop design-oriented and creative solutions.	0.260	$p > 0.05$
M9	Tools and equipment made by drawing inspiration from nature make life easier.	3.142	$p < 0.05$
M10	Biomimicry can be used in problem-solving and developing new technologies.	0.527	$p > 0.05$
M14	Imitating nature can provide individuals with new perspectives.	0.595	$p > 0.05$
M16	Using nature and technology together in science education enables the development of new products.	0.392	$p > 0.05$
M19	Drawing inspiration from nature can accelerate the problem-solving process.	3.819	$p < 0.05$

When the data in Table 4 are examined, it is found that teachers' STEM awareness scores did not differ significantly according to their responses to M3 ($p > 0.05$), which focuses on the theoretical and interdisciplinary definition of biomimicry; M5 ($p > 0.05$), which includes its pedagogical purpose; M10 ($p > 0.05$), which addresses its technological functionality; M14 ($p > 0.05$), which reflects its philosophical dimension; and M16 ($p > 0.05$), which questions nature-technology integration. By contrast, statistically significant differences were found in items related to the practical and problem-solving-oriented outputs of biomimicry.

A significant overall difference was found among STEM awareness scores according to responses to the statement 'Tools and equipment made by drawing inspiration from nature make life easier' (M9) ($F = 3.142$; $p < 0.05$).

Similarly, in the item 'Drawing inspiration from nature can accelerate the problem-solving process' (M19), a significant variation was detected in general STEM awareness scores according to teachers' responses ($F = 3.819$; $p < 0.05$). When mean scores were examined, teachers who answered 'yes' to this item had higher STEM awareness than the other groups.

However, despite these overall ANOVA significances obtained for M9 and M19, Scheffe and Tukey HSD multiple comparison (post-hoc) tests conducted to determine between which groups (Yes-No, Yes-I have no idea, No-I have no idea) the difference occurred found no statistically significant difference in any pairwise combination. The absence of a clear pairwise difference in post-hoc analyses may be due to unequal sample distributions across groups, especially the low number of respondents answering 'no' and 'I have no idea', and the highly conservative structure of the Scheffe test in preventing Type I error. Nevertheless, the fact that the difference between the 'yes' and 'I have no idea' groups in M19 approached the significance boundary ($p = 0.05$) provides a pedagogical clue that teachers who internalize the practical/functional aspect of biomimicry tend to display a stronger integrated STEM vision.

One of the most original outputs of the study is that not every dimension of biomimicry awareness is in a linear relationship with STEM awareness. While items concerning the educational and theoretical aspects of biomimicry did not create a significant effect on STEM awareness, practical/design-oriented items such as the idea that nature-inspired tools make life easier and accelerate problem-solving processes showed strong links with STEM awareness.

When teachers see biomimicry not as an abstract biological concept but as a practical problem-solving method blended with engineering and technology, they match it with their STEM vision. Therefore, nature-inspired sustainable designs have the potential to provide a functional context for enriching STEM activities.

5. Recommendations

5.1 Curriculum and Integration

In current process-oriented and interdisciplinary curricula such as the Turkish Century Education Model, biomimicry-based STEM activities should be included with practical examples. Teacher guide booklets and activity pools showing how biomimicry can be associated with science learning outcomes should be developed.

5.2 Applied In-service Training

STEM and biomimicry trainings to be organized for teachers should go beyond theoretical presentations and be designed as workshop-based programs focused on material development, experiencing design cycles, and simulating classroom budget/time management.

5.3 Inclusive Education Policies

In planning STEM trainings, rather than focusing on demographic distinctions such as seniority, gender, or school type, inclusive and sustainable support mechanisms should be established to remove classroom integration barriers, particularly material and time-management barriers, for all teacher groups.

5.4 For Future Research

In future studies, not only teachers' awareness but also their classroom implementation performance and pedagogical content knowledge should be examined in depth through qualitative or mixed designs, including observation, interviews, and action research.

6. Conclusion

This study revealed that science teachers generally have positive attitudes toward biomimicry and high levels of STEM awareness; however, their knowledge of biomimicry remains largely intuitive rather than conceptually comprehensive. Although many teachers had not previously encountered the concept, they recognized its potential contributions to problem-solving, innovation, and science education.

The findings also showed that teachers strongly believe in the benefits of STEM education for students, while experiencing hesitation regarding classroom implementation due to practical constraints such as time, materials, and curriculum demands. Furthermore, STEM awareness did not differ significantly according to gender, professional seniority, school type, or prior STEM training.

A key finding of the study is that STEM awareness is associated more strongly with the practical and problem-solving dimensions of biomimicry than with its theoretical aspects. Teachers who viewed nature-inspired designs as useful tools for solving real-life problems tended to demonstrate higher STEM awareness. Therefore, biomimicry can serve as an effective context for enriching STEM education by connecting science, technology, engineering, and nature-inspired design processes. To realize this potential, greater emphasis should be placed on integrating biomimicry into teacher education, professional development programs, and classroom practices.

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Ethics Statement
The study was approved by the Ethics Committee of Adıyaman University (Approval No: 347, Date: 22/11/2022). Participation was voluntary, and informed consent was obtained from all participants.

Authors' Contributions
Gamze Ekici contributed to the conception of the study, data collection, and the preparation of the master's thesis on which this article is based. Murat Aydın supervised the research process, contributed to the study design, data analysis and interpretation, substantially revised and developed the manuscript and prepared the final version for publication. Both authors reviewed and approved the final manuscript.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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