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Development of the Biomimicry Teaching Self-Assessment Scale

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Abstract

The purpose of this study is to develop a self-assessment scale designed to measure teachers' competencies in biomimicry teaching. The sample consists of 543 teachers. The validity of the scale was established through an extensive literature review, comparisons with existing instruments, and expert evaluations. The reliability of the scale, as measured by Cronbach's alpha coefficients, ranged from 0.74 to 0.95. Exploratory factor analysis revealed that the 27 items in the scale were grouped under six factors: attitude towards biomimicry teaching, awareness of biomimicry applications, attitude towards nature, awareness of biomimicry concepts, self-assessment of biomimicry pedagogy, and self-efficacy in biomimicry teaching. This six-factor structure accounted for 70.08% of the total variance. Confirmatory factor analysis indicated that factor loadings ranged from 0.41 to 0.98. The stability of the scale was assessed using the test-retest method. To ensure external validity, a correlation analysis was conducted between the scores of this scale and the Environmental Literacy Scale for Adults, revealing a strong positive relationship. Overall, the Self-Assessment Scale for Biomimicry Teaching has been shown to be a valid and reliable instrument for assessing teachers' competencies in biomimicry instruction based on their self-perceptions.

Keywords: Biomimicry Teaching, Teacher Competencies, Scale Development

Introduction

Learning from nature is just as important as learning about nature in human life. The first pieces of knowledge and tools created by humans through inspiration from nature demonstrate the course of historical development. In the early years of humanity, various aspects of life such as nutrition (Mithen, 1996), protection and shelter (Klein, 2009), agriculture (Smith, 1998), the use of medicinal plants (Hoffmann, 2003), and even the discovery of calendars through seasonal changes (Aveni, 2001) serve as just a few of the countless examples indicating that nature was humanity's first teacher. In fact, individual learning processes are also deeply rooted in nature. Children's interactions with their natural environment enable them to learn through observation and experience. This aligns with Jean Piaget's theory of cognitive development, which emphasizes that children actively explore their surroundings to acquire knowledge (Piaget, 1952). Similarly, Vygotsky highlights the importance of social interaction and proximal environmental factors in the learning process, suggesting that people develop knowledge and skills through interactions with others while facing challenges and opportunities presented by nature (Vygotsky, 1978).

Additionally, the learning methods of animals shed light on human learning processes. For instance, social learning in animals enables individuals to acquire knowledge by observing the behavior of others (Bandura, 1977). In this context, the richness that nature offers plays a fundamental role in human learning processes. Educational approaches that aim to teach through inspiration from nature, such as the Montessori and Reggio Emilia methods, prominently embody this concept (Edwards, 2002; Montessori, 1964). These examples clearly demonstrate the influence and significance of nature in learning.

Before the establishment of formal schooling, education was based on natural learning processes, which formed the foundation of Rousseau's educational philosophy. During this transitional period, Rousseau emphasized the importance of nature in education, advocating for learning through personal experiences (Rousseau, 1762), a perspective that aligns with naturalism (Gutek, 2001). Naturalism aims to create a learning environment suited to an individual's nature, and Rousseau's work *Emile* underscores the idea that individuals should learn through direct interaction with nature. In this context, engagement with the natural environment laid the groundwork for fostering individual learning and discovery in the transition to formal education. Rousseau argued that human intervention in education was often premature, asserting that education should begin later and progress slowly, in harmony with nature's rhythm. The fundamental difference between nature-based education and human-driven education, according to Rousseau, is that while nature stimulates the senses directly, human education relies on imagination to activate the senses (Rousseau, 2010: 594). By systematically integrating nature into education, Rousseau emphasized that anything not originating from nature was inherently opposed to it.

John Dewey adopted Rousseau's naturalist perspective, advocating for children's experiential learning in nature (Bal, 1991: 41). Ultimately, Rousseau viewed nature and the teacher as partners in education, suggesting that during early years, nature should be prioritized, while the teacher's role should become more prominent as abstract thinking develops. Considering these ideas, it can be argued that the philosophical foundations of biomimicry are rooted in naturalism.

All these experiential and theoretical explanations have led to the development of the concept of learning inspired by nature while simultaneously learning about nature. The terms biomimicry, biotechnology, bionics, biomimetics, and biomechanics share similar meanings, as they all examine the mechanical principles of living organisms (Hall, 2019) and are fundamentally based on the idea of "learning from nature." However, there are subtle differences in their meanings.

Biotechnology, bionics, biomimetics, and biomechanics represent engineering and technological fields that are based on biological systems. Biotechnology focuses on developing products and processes using living organisms (Crueger & Crueger, 2000), while bionics designs artificial systems that mimic human body functions (Landolt & Sanderson, 2012). Biomimetics or biomimicry seeks solutions to various challenges by drawing inspiration from nature (Lehn & Benyus, 2012). These fields aim to create innovative solutions by understanding biological systems and integrating them into engineering applications, and they often overlap in their areas of implementation.

The term biomimicry was first introduced by Janine Benyus in 1997. The word "bio" means "life," while "mimicry" means "to imitate." Benyus (1997) defines biomimicry as the practice of studying and imitating nature's systems, processes, and models to develop solutions for human problems. However, biomimicry should not be seen merely as an act of imitating nature. In the literature, biomimicry is defined based on three key variables: (1) mimicking the form or function of a natural structure, (2) imitating natural processes, and (3) replicating natural systems (Benyus, 1997; Kenny et al., 2012). Biomimicry education involves the teaching of these fundamental principles.

The Pedagogy of Learning from Nature

Biomimicry is an outdoor learning and teaching method. Outdoor education is considered a significant component in environmental education and personal-social development (Higgins & Nicol, 2002). Such activities instill in children an awareness of environmental conservation and the responsibility of ensuring a sustainable environment for future generations. When students actively and responsibly engage in education alongside their teachers, they develop into environmentally literate individuals (Akçadağ & Çobanoğlu, 2020). Research has shown that learning in outdoor settings enhances cognitive learning and fosters positive emotions toward these environments (Anderson et al., 2006; Anderson et al., 2002; Ash, 2003; Balkan Kıyıcı & Atabek Yiğit, 2010; Bozdoğan, 2012; Bozdoğan & Ustaoğlu, 2014; Bozdoğan & Yalçın, 2006; Eraut, 2004; Ertaş et al., 2011; Griffin, 2004; Öner & Güneş, 2017; Özgen, 2011; Türkmen, 2018). Additionally, studies have confirmed that knowledge acquired in such environments is retained for longer periods (Anderson et al., 2002; Falk & Dierking, 1997).

In this context, biomimicry establishes its own unique instructional methodology, known as biomimicry pedagogy. Students who acquire knowledge and fundamental as well as advanced skills through this approach develop a greater ability to identify real-world problems and find new solutions, ideas, and products by drawing inspiration from nature's existing solutions.

As an innovative educational approach that enhances children's knowledge, skills, values, and attitudes through learning from nature, biomimicry education enables students to explore engineering design and nature while fostering engagement in various scientific disciplines (such as life sciences, chemistry, physics, and engineering) (Eggermont, 2007). By teaching nature's design principles, biomimicry education provides students with the opportunity to develop sustainable solutions. Research indicates that such an educational approach enhances students' cognitive learning and fosters positive emotions toward outdoor learning environments (Anderson et al., 2006).

Biomimicry education encourages analogical thinking, helping students understand natural functions and mechanisms through analogy and apply this knowledge to design processes (Stevens et al., 2019). Furthermore, biomimicry strengthens analytical thinking and problem-solving skills by utilizing various examples from nature to help students understand how natural systems function (Bar-Cohen, 2005). By studying natural systems, children gain the opportunity to integrate this knowledge into engineering applications. While outdoor education fosters children's awareness of environmental conservation and sustainability, it is equally important for teachers to learn effective biomimicry teaching methods (Higgins & Nicol, 2002; Sandell et al., 2005).

Biomimicry education is supported by project-based learning methods. This helps students develop their creativity and problem-solving skills (Stevens et al., 2019). Additionally, this approach can be effectively implemented through various teaching methods such as inquiry teaching, problem-based learning, and cooperative teaching. Inquiry teaching allows students to scientifically explore systems and processes in nature, while problem-based learning encourages them to use biomimicry principles to solve real-world problems (Hmelo-Silver, 2004). Cooperative teaching enables students to interact within a group and work on biomimicry projects, which supports social learning and critical thinking (Johnson & Johnson, 1999). Using scientific research methods allows students to systematically examine examples in nature and apply this knowledge with a data-driven scientific method to develop innovative solutions (Barrow, 2006). As a result, biomimicry helps students develop creative thinking and problem-solving skills by interacting with nature through these teaching methods.

Research shows that regular contact with nature strengthens children's connection to nature (Mecinska et al., 2024). Therefore, education should take place not only in schools but also outside of schools. Thanks to the solutions that living organisms in nature develop in response to the problems they encounter, designers have also begun to follow a similar path and have turned to approaches that imitate nature to overcome challenges (Karabetça, 2016; Yıldız, 2012). As a result of this tendency, the science and teaching of biomimicry have emerged. Biomimicry is an approach that seeks solutions to problems in engineering, design, and other fields by drawing inspiration from nature. By integrating biomimicry into educational processes, teachers can enhance students' creativity and problem-solving skills (Aksit & Wiebe, 2019; Cuperman & Verner, 2019), support their analogical reasoning abilities (Cuperman & Verner, 2013; Clement & Rea-Ramirez, 2008), and design interdisciplinary learning processes (Barber, 2015; Bernstein et al., 2021).

Research conducted in the past decade shows that in biomimicry education, teachers are not just information transmitters but also facilitators, motivators, and guides in learning processes. In this context, the role and importance of teachers in biomimicry education manifest in areas such as pedagogical approaches, technology integration (Deveci Topal et al., 2021; Mitnik et al., 2009), the support of artificial intelligence and robotics applications (Sullivan, 2008; Sullivan & Heffernan, 2016), and increasing students' interest in STEM fields (English, 2016; English & Mousoulides, 2015). In this respect, teachers' competencies in biomimicry education are of great significance.

Teachers' Competencies in Biomimicry Teaching

For biomimicry education to be effectively implemented, teachers must possess specific competencies. First and foremost, it is essential for teachers to develop an awareness of viewing nature as both a source of inspiration and a teacher. To be successful in biomimicry teaching, teachers must believe in its importance and be motivated to teach it. Having a positive attitude toward conducting lessons not only inside the classroom but also in outdoor environments (Aytaç, 2014; Baker, 2016; DeWitt & Storksdieck, 2008; Lee & Witz, 2009) helps students make sense of the world, fostering curiosity, inquiry, and the ability to research and share findings just like a scientist. To achieve this, teachers need to be familiar with nature, hold positive attitudes toward it, overcome any fear of natural structures, and actively engage in environmental conservation. Teachers who are sensitive to environmental and sustainability issues help students develop positive attitudes toward nature (Coban & Coştu, 2021). This awareness encourages students to become sensitive to environmental problems, take an active role in protecting nature, and cultivate these skills in their own students. This process enhances teachers’ ability to effectively convey knowledge, thereby playing a critical role in students' understanding of biomimicry processes and interactions with nature (Wanieck et al., 2020). Teachers' knowledge and awareness of nature, as well as their understanding of drawing inspiration from it, are equally important.

Having knowledge of biomimicry concepts and applications allows teachers to teach students how to take inspiration from nature (Stevens et al., 2019). According to Rousseau's naturalistic education philosophy, teachers and nature function as partners in the learning process. Nature is responsible for developing individuals physically, while the teacher is responsible for developing them spiritually. It is accepted that teachers’ understanding of biomimicry pedagogy, including its definitions, concepts, ideas, and principles, helps students internalize the concept of learning from nature (Roobeek, 2019). Being a role model in biomimicry education is crucial for teachers. Their positive relationships with nature can influence students' interest in learning about and engaging with nature (Torkar, 2019). Teachers should guide students in constructing knowledge using scientific process skills and applying this knowledge in social contexts.

For effective teaching, teachers must possess pedagogical content knowledge (Abd-El-Khalick, 2013; Demirdöğen et al., 2016; Schwartz & Lederman, 2002; Wahbeh & Abd-El-Khalick, 2014). Pedagogical content knowledge refers to the integration of pedagogy and subject matter, addressing both "what" and "how" aspects of teaching (Nouri et al., 2021; Shulman, 1986). This requires teachers to combine biomimicry's definitions, concepts, ideas, and principles with instructional methodologies. Biomimicry education is best facilitated through experiential learning and hands-on project-based instruction. Biomimicry pedagogy involves interdisciplinary teaching design, project-based learning, inquiry-based teaching, and cooperative teaching strategies. Additionally, it incorporates real-life connections, problem-solving, design thinking, and creative scientific thinking skills (Stevens et al., 2019).

Thus, teachers must develop pedagogical strategies that encourage students to design by drawing inspiration from nature (Çoban & Coştu, 2023). If teachers expect students to create assignments, projects, or design-based learning products, they must integrate the philosophy and pedagogy of biomimicry into their teaching. Such pedagogical approaches help students enhance their creative thinking skills. Therefore, teachers should use appropriate teaching methods and techniques to create optimal learning environments that guide students in constructing knowledge through scientific skills and applying their learning in real life (Gerber et al., 2001; Griffin & Symington, 1997; Krakowka, 2012).

Teachers' attitudes toward nature and their participation in nature-related activities enhance their environmental literacy levels (Kahyaoğlu, 2011). Outdoor education provides teachers with the opportunity to learn alongside their students and benefit from these experiences. Additionally, pre-service nature education programs have been reported to increase prospective teachers' awareness of nature (Keleş, Uzun, & Uzun, 2010). Therefore, selecting activities that enhance teachers' professional skills makes outdoor activities more effective (Lugg & Slattery, 2003).

Teachers' familiarity with nature plays a critical role in shaping students' environmental awareness and attitudes toward nature. Research has shown that teachers' relationships with nature influence the integration of nature-themed content into teaching processes (Elliott, 2019). Teachers who understand nature can more effectively guide students on nature conservation and sustainability issues. Moreover, studies have found that teachers who interact with nature help students develop more positive attitudes toward it (Chawla, 2009). In this context, teachers' knowledge and attitudes toward nature enhance the quality of environmental education and strengthen students' connection with nature. Increasing teachers' understanding and awareness of nature is of great importance in achieving the education system’s goal of fostering environmental consciousness.

Evaluation of Teachers' Competencies in Biomimicry Teaching

Teacher competencies are an important factor that directly affects the quality of education. Competency is defined as "the knowledge, skills, or attitudes that enable a particular profession or function to be performed effectively at expected standards" (Birnbaum & Daily, 2009). In the context of education, competency is defined as the examination of specific knowledge and abilities considered important for success in teaching (Al-Mutawa & Al-Dabbous, 1997). The nature of the competencies teachers need to possess is of critical importance, as it directly influences student learning (Vikstrom, 2008). In this context, for biomimicry pedagogy to achieve its goals, it is necessary to determine the knowledge, skills, and attitudes required for teachers and how these can be assessed (Nouri et al., 2021).

Various frameworks have been developed to categorize teacher competencies. Cebrián and Junyent (2015) propose that teachers should acquire competencies related to knowledge, practical skills, ethical values, attitudes, and emotions. Blömeke and Delaney’s (2012) model, which has been adopted as a conceptual framework based on literature reviews to determine new teacher competencies, divides teacher competencies into two subcategories.

In this model, cognitive abilities include content knowledge, pedagogical content knowledge, which addresses the "what" and "how" questions of teaching (Shulman, 1986), and general pedagogical knowledge (Schwartz & Lederman, 2002). Abd-El-Khalick (2013) highlights the importance of pedagogical content knowledge in biomimicry teaching and states that teachers must be aware of students' misconceptions about biomimicry.

The second main category includes affective-motivational characteristics, which encompass professional beliefs, motivation, and self-regulation. In the context of biomimicry teaching, knowledge of scientific content and awareness of the value of biomimicry education (Lee & Witz, 2009) are significant elements affecting teaching and should be considered when evaluating teachers (Abd-El-Khalick et al., 2013; Wahbeh & Abd-El-Khalick, 2014). Teachers' attitudes and motivation toward teaching biomimicry are crucial for the effectiveness of the teaching process.

A high level of self-efficacy among teachers is essential for the effective implementation of biomimicry pedagogy. Teachers must develop their knowledge and skills in this field to best convey nature-inspired learning processes to their students. Lee and Witz (2009) state that teachers' competencies in understanding natural systems and processes directly impact students' learning experiences in this area. Furthermore, teachers' ability to comprehend nature's engineering solutions and integrate this knowledge with pedagogical approaches plays a vital role in developing students' critical thinking and problem-solving skills. Therefore, teachers' self-efficacy in biomimicry pedagogy should be strengthened, and they should be supported in gaining practical experience in this process (Abd-El Khalick, 2014).

Nouri et al. (2021) emphasize that teachers must possess certain essential competencies for effective nature education. Teachers must believe in the importance of nature education and have the motivation to teach it. Additionally, they should be able to identify the necessary components for instruction and recognize the relationships between these components. Teachers must also have knowledge of relevant scientific content and scientific literacy, be aware of potential misconceptions, and design learning experiences that consider students' diverse characteristics, ensuring effective learning for all students. Furthermore, possessing general pedagogical knowledge and integrating this knowledge into biomimicry education is a crucial requirement. They must also be able to select and implement research-based pedagogical approaches and teaching strategies while designing and modifying appropriate tools and methods to evaluate biomimicry teaching practices.

Atabek-Yiğit et al. (2014) highlight the key characteristics that teachers should possess for assessing biomimicry competencies. These characteristics include knowledge of biomimicry, pedagogical content knowledge, motivation and sensitivity to attitudes, environmental and ecological literacy, assessment knowledge, and self-efficacy in biomimicry pedagogy (Tschannen-Moran & Woolfolk Hoy, 2001). These elements are essential for teachers to effectively participate in the biomimicry education process. In conclusion, the evaluation of teachers' competencies in biomimicry teaching should consider the following aspects: Biomimicry knowledge, Pedagogical content knowledge, Motivation and sensitivity to attitudes, Environmental and ecological literacy, Assessment knowledge, Self-efficacy, Research-based pedagogical approaches, Practical experience.

Problem Statement

In today's world, the dominance of urban life and increased interaction with electronic devices have significantly reduced children's contact with nature (Freuder, 2006). This situation has led to the emergence of generations that have little familiarity with nature and have become dependent on schools to gain knowledge about environmental issues. However, one of the fundamental goals of education is to help students develop valid, effective, and productive perspectives on nature. This goal has been further emphasized in the last century, particularly through the Next Generation Science Standards (NGSS) in the United States (NGSS Lead States, 2013).

Children’s education, when disconnected from nature, results in a lack of familiarity with the natural world, which in turn fosters fear and anxiety about nature (Children & Nature Network, 2020; Sobel, 2008). These fears not only hinder children's ability to understand the environment but also create significant weaknesses in their ability to learn from nature.

The pedagogy of learning from nature is an essential competency that teachers must possess. Although various trainings, courses, and projects have been implemented to teach teachers how to help students learn from nature, the specific competencies that teachers need to effectively teach biomimicry have not been clearly identified. Additionally, there are currently no assessment tools available to measure teachers' competencies in teaching biomimicry, either in their current state or after undergoing a training program.

To date, qualitative research has attempted to identify the competencies teachers should have regarding nature and environmental education (Atabek-Yiğit et al., 2014; Nouri et al., 2021). These studies reveal that 69% of teachers are unfamiliar with the concept of biomimicry and often confuse it with bionics, biomimetics, biotechnology, and biomechanics. Furthermore, it has been found that teachers tend to associate biomimicry with engineering, architecture, and economics rather than education, and their awareness of the topic remains at a moderate level (Çakır, 2019; Tavşan, 2021). Additionally, 95% of teachers lack sufficient knowledge of nature education, and 61.1% never use outdoor teaching methods (Ekici, 2015).

Despite the growing interest in biomimicry as an innovative teaching approach, there remains a significant gap in understanding and assessing its practical implementation in the classroom. The problem is scientifically analyzed by integrating insights from educational psychology and pedagogical theories, which highlight the need for reflective teaching practices (Schön, 1983; Borko et al., 2008). In this context, previous research has underscored the importance of validated self-assessment tools in promoting continuous improvement among educators (Faikhamta et al., 2022). However, most existing instruments do not adequately address the unique challenges of biomimicry teaching. Therefore, this study employs a systematic methodology combining qualitative and quantitative analyses to develop a comprehensive self-assessment scale that fills this gap, ensuring that the problem is not only theoretically grounded but also empirically investigated.

These findings highlight teachers' inadequacies in utilizing learning opportunities in nature and enhancing interaction with the natural environment. It is also evident that nature-based educational approaches, such as forest pedagogy, are not widely adopted by teachers, and various challenges arise in practical applications. However, these research findings are based on qualitative data, and there is a need for a quantitative measurement tool to assess these competencies systematically.

Biomimicry, which integrates principles from nature into human problem-solving, has emerged as a powerful pedagogical approach in science education due to its potential to foster sustainability thinking and interdisciplinary learning (Durrant, 2020; Yen et al., 2019). However, there is a notable gap in practical, research-based tools that enable educators to assess and improve their biomimicry teaching practices (Faikhamta et al., 2022). Although reflective teaching is recognized as a cornerstone of professional growth (Schön, 1983; Borko et al., 2008), most existing self-assessment instruments fail to address the specific challenges of biomimicry instruction. This study scientifically addresses this problem by combining a thorough literature review, expert validation, and statistical analysis to construct a domain-specific self-assessment scale. Through this multi-layered approach, the research problem is examined not only in terms of educational theory but also through robust empirical methods, contributing a validated tool to both practice and scholarship.

In this context, developing a scale to measure teachers' competencies in biomimicry teaching will help address the knowledge gaps in this field and contribute to enriching educational processes by integrating nature-inspired learning approaches.

Research Objective

The objective of this study is to develop a self-assessment scale to measure teachers' competencies in biomimicry teaching. The study aims to evaluate the validity, reliability, and structural alignment of the scale in assessing teachers' knowledge of biomimicry, pedagogical skills, motivation, and attitudes toward teaching nature-inspired learning.

Method

Research Model and Design

This study is a scale development research. Accordingly, a rigorous methodology was applied to determine the validity and reliability of the Biomimicry Teaching Self-Assessment Scale (BTsAS). The development process followed established psychometric standards and included the following steps: item generation and content validation, study group selection and implementation, construct validity and reliability analyses, discrimination analysis, test-retest reliability, and criterion-related validity.

Construct validity was examined through both exploratory and confirmatory factor analyses (EFA and CFA). EFA was conducted to identify the underlying factor structure, while CFA was used to test the fit of the model using a separate sample. The scale's criterion validity was evaluated by correlating it with an existing validated instrument. Reliability analyses included internal consistency (Cronbach's alpha and Omega coefficients), test-retest reliability, and item-total correlations. The methodology aligns with accepted approaches to scale development in educational research (DeVellis, 2017; Boateng et al., 2018).

Population and Sample

The participants in this study were 543 teachers selected from various educational institutions across Turkey, ensuring diversity in academic and professional backgrounds. Among the participants, 69.24% were female and 30.76% male. Age distribution was as follows: 18.05% aged 20-33, 45.67% aged 34-43, 28.91% aged 44-53, and 7.37% aged 54 and above. Educational levels included bachelor's (46.59%), master's (50.46%), and doctoral degrees (2.95%). Teaching levels were: preschool (16.35%), primary (31.49%), middle (27.07%), and high school (24.86%). Geographically, participants were distributed among city centers (42.17%), metropolitan areas (30.94%), districts (19.89%), and rural areas (6.81%). The sample was balanced across Turkey's seven geographical regions, with each region represented by approximately 70-80 teachers.

Data Collection Tools

In this study, the Biomimicry Teaching Self-Assessment Scale (BTsAS) was developed, and for criterion validity, the "Environmental Literacy Scale for Adults (ELSA)," developed by Atabek-Yiğit et al. (2014), was used.

The Environmental Literacy Scale for Adults (ELSA) was employed to determine criterion validity. This scale was designed to assess the environmental literacy levels of individuals aged 18 and above. Validity and reliability analyses were conducted using data from 332 participants. The scale consists of three sub-dimensions: "environmental consciousness," "environmental concern," and "environmental awareness." The scale comprises 20 items, each rated on a five-point Likert scale. The Cronbach’s alpha reliability coefficients were found to be

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0.881 for the overall scale, 0.807 for environmental consciousness, 0.765 for environmental concern, and 0.715 for environmental awareness. The scale serves as a crucial tool for measuring individuals' attitudes, knowledge, and behaviors regarding the environment and nature, thereby assessing their level of environmental literacy.

Development of the Biomimicry Teaching Self-Assessment Scale (BTsAS)

During the development of BTsAS, a literature review was conducted to align the process with existing scale development methodologies. Existing scales (Aslan et al., 2008; Aydın, 2010; Çabuk & Karacaoğlu, 2003; Ek et al., 2009; Kaya et al., 2009; Yeşilyurt et al., 2013) were analyzed.

Next, the competencies teachers need to teach biomimicry to children were identified. National and international studies in this field were reviewed to extract statements for the scale. Through needs analysis, meta-analysis (Nouri et al., 2021), and teacher competencies related to nature literacy, the most essential teacher characteristics were listed. These competencies are discussed in the literature review section.

In line with the item pool creation process proposed by Carpenter (2018) and DeVellis & Thorpe (2021), a preliminary pool of 38 items was developed. Experts' opinions (Büyüköztürk, 2011) were sought regarding the coherence of the items with the overall scale, wording of the statements, suitability of each item for relevant sub-dimensions, and appropriateness of the items as scale components. To incorporate expert feedback, the preliminary scale was continuously refined. Experts evaluated each item using a three-point scale: "Appropriate," "Needs Revision," or "Should Be Removed." All expert feedback forms were compiled into a single document to determine the number of experts who approved each item. Based on expert opinions, the content validity of the items was assessed using the content validity ratio developed by Veneziano & Hooper (1997). These ratios were calculated by dividing the number of experts who provided positive feedback for each item by the total number of experts and subtracting one. The content validity index values were determined based on the number of experts and the obtained content validity ratios. Items with a content validity ratio below 0.80 were removed from the study. Additionally, modifications were made in accordance with calculations in certain articles to enhance comprehension. Following these steps, a trial form consisting of 31 items was created.

Pilot Study

After completing the item pool, pilot studies were conducted to assess the comprehensibility of the scale items and the average response time. A total of 40 teachers, with 10 teachers from each subject area, participated in the pilot study. During the implementation of the BTSAS, administrators read each item to the teachers individually and asked them to explain their understanding of the items. Items found to be difficult to comprehend were reworded. Thus, the initial form of the scale, consisting of 31 items, was finalized.

The final version of the scale consists of 31 items, rated on a five-point Likert scale ranging from "Strongly Agree – 5 points" to "Strongly Disagree – 1 point." Considering the age range of respondents and the frequent use of odd-numbered scales in educational research (Tezbaşaran, 1997), a five-point Likert scale was chosen (Strongly Agree – 5 points, Agree – 4 points, Neutral – 3 points, Disagree – 2 points, Strongly Disagree – 1 point). The finalized scale was administered to the sample, and its validity and reliability were determined through statistical analyses.

Data Collection

The data were collected in 2024 from teachers working in various geographical regions of Turkey. The scale was converted into an online form, and the link to the form was shared in different messaging groups where teachers were members. The purpose, content, duration, and voluntary nature of participation in the study were explained in these messaging groups. Teachers who volunteered to participate completed the scale online.

In the first section of the online form, it was explicitly stated once again that participation was voluntary and that participants had the right to withdraw from the study at any time. The responses provided by the participants were downloaded in Excel format for data analysis.

Data Analysis

The construct validity of the Biomimicry Teaching Self-Assessment Scale (BTsAS) was examined using confirmatory factor analysis (CFA). Item analysis was conducted to determine the discriminative power of the scale items. The reliability of the measurement tool was evaluated by calculating Cronbach's alpha and test-retest reliability coefficients. The criterion validity of the scale was assessed by examining the relationship between the scores obtained from BTsAS and the Environmental Literacy Scale for Adults (ELSA) developed by Atabek-Yiğit et al. (2014). The analyses were conducted using SPSS 25.0 and AMOS 24.0 statistical software packages.

The scale development process followed established procedures outlined in the literature (DeVellis, 2017; Boateng et al., 2018). An initial item pool of 45 statements was generated based on a comprehensive review of relevant literature on biomimicry and teacher competencies. Content validity was ensured through evaluations by seven field experts, leading to the refinement of items. The scale was piloted with 543 in-service teachers selected through convenience sampling. Exploratory Factor Analysis (EFA) was conducted using Principal Axis Factoring and Varimax rotation; the Kaiser-Meyer-Olkin (KMO) value was 0.91, and Bartlett’s Test of Sphericity was significant ($p < .001$). A six-factor structure explaining 70.08% of the total variance was identified. Confirmatory Factor Analysis (CFA) supported the model fit ($\chi^2/df = 2.34$, CFI = .95, RMSEA = .046). Internal consistency was measured using Cronbach’s alpha, ranging from 0.74 to 0.95. Test-retest reliability was assessed after a two-week interval. External validity was examined by correlating scale scores with the Environmental Literacy Scale for Adults, revealing a strong positive relationship.

Validity and Reliability Analysis Results

To explore the factor structure of the BTsAS, Exploratory Factor Analysis (EFA) was applied. EFA is a statistical technique used to understand the relationships between observed variables and identify underlying latent factors (Yurt, 2023). This analysis aims to reduce complex interrelationships among multiple variables into meaningful fundamental factors. EFA was conducted with data from 470 participants using SPSS 28.0.

To determine the fit level of the scale structure identified through EFA, Confirmatory Factor Analysis (CFA) was conducted. CFA is a statistical technique used to test a predefined factor structure based on a theoretical model. Unlike EFA, in CFA, researchers test a pre-established model and evaluate how well it fits the dataset (Çokluk et al., 2012). A different sample (n=450) was used for CFA, and the analysis was conducted using AMOS 24.0.

The reliability of the scale was assessed by calculating Cronbach's alpha and Omega coefficient. These coefficients range from 0 to 1. Alpha values between 0.60 and 0.80 indicate considerable reliability, while values between 0.80 and 1 indicate high reliability (Özdamar, 2004).

To evaluate discriminant validity, an item analysis was conducted (Tavşancıl, 2005). The total scores obtained from BTsAS were ranked from highest to lowest. Participants in the top 27% were categorized as the upper group, while those in the bottom 27% were categorized as the lower group. The independent samples t-test was used to compare the scores obtained from scale items between these groups. The same data set used for CFA (n=450) was also used for discriminant validity analysis. All analyses were conducted using SPSS 28.0 statistical software.

Findings

Exploratory Factor Analysis Results

Before conducting Exploratory Factor Analysis (EFA), the Kaiser-Meyer-Olkin (KMO) coefficient was calculated, and Bartlett's Test of Sphericity was applied to assess the suitability of the dataset for factor analysis. The KMO value ranges between 0 and 1. A KMO value < 0.50 indicates that the sample size is insufficient for factor analysis, while a KMO value > 0.90 suggests an excellent level of adequacy (Field, 2013).

Bartlett's Test of Sphericity evaluates whether the correlations between variables in the dataset are statistically significant. If the test produces a statistically significant result ($p < 0.05$), it indicates a significant relationship among the variables. These criteria help determine the effectiveness of factor analysis and the suitability of the dataset for this type of analysis (Field, 2013).

Table 1. KMO Coefficient and Bartlett's Test of Sphericity Results

KMO.		0,87
Bartlett's Test of Sphericity	Chi-Square	9558,00
	Df	351
	p	<0,001

Examining Table 1, the KMO coefficient is 0.87, indicating that the sample size is highly suitable for factor analysis. Based on the results of Bartlett's Test of Sphericity, a significant relationship exists among the variables (Chi-square = 9558.00; df = 351; $p < 0.001$). These findings confirm that the dataset is suitable for factor analysis. Since the necessary assumptions were met, the next step involved conducting factor analysis.

Factor analysis was performed using the Principal Axis Factoring (PAF) extraction method. This method was preferred because it focuses on extracting common variance among the variables and identifying the underlying factors in the dataset. Principal Axis Factoring specifically considers the correlation structures between variables, making the extracted factors more realistic and meaningful (Yurt, 2023).

The factor loading cutoff point was set at 0.40, as items with factor loadings of 0.40 or higher are considered to contribute significantly to the variance of the factor they belong to (Stevens, 2012). EFA identified six factors with eigenvalues greater than one. Additionally, the scree plot of eigenvalues indicated a noticeable decrease in slope after the seventh point. According to parallel analysis, the scale exhibits a six-factor structure (Figure 1). These findings suggest that the scale items tend to cluster under six factors. In the next step, the number of factors was fixed at six, and factor analysis was repeated.

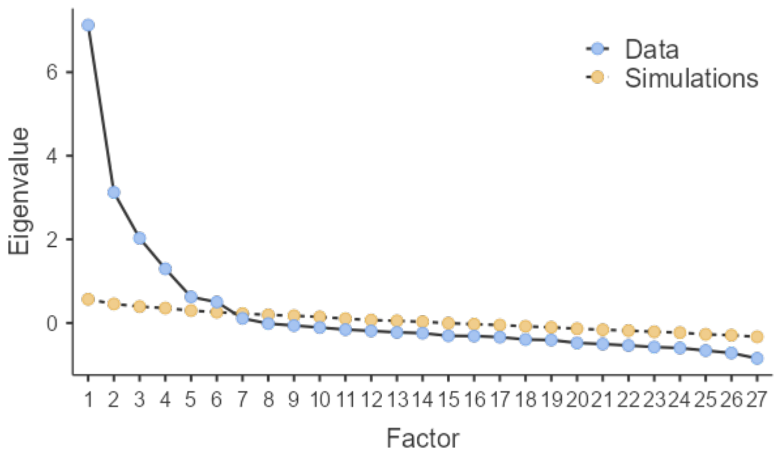

Figure 1. Eigenvalue Factor Graph

To make the items clustered within factors more distinct and to facilitate easier interpretation of results, the Varimax rotation technique was applied. Varimax rotation minimizes the correlation between factors, making it easier to interpret the factor structure clearly. This method is particularly used to eliminate complexity among existing factors and define each factor more independently and explicitly (Yurt, 2023). As a result of the analysis, four items (m6, m13, m15, and m20) with factor loadings below 0.40 were individually removed from the scale, and the analysis was repeated multiple times.

The variance explained by the six-factor scale and the factor loadings of the scale items are presented in Table 2.

Table 2. Exploratory Factor Analysis Results of the Biomimicry Teaching Self-Assessment Scale

F. N	Item No	Items	1	2	3	4	5	6
1	m30	30. I believe that activities inspired by nature contribute to students developing a positive attitude toward nature.	***0,88***	0,06	0,01	0,05	0,14	-0,01
	m27	27. I believe it is necessary to provide teacher candidates with training on teaching inspiration from nature in undergraduate education.	***0,86***	0,14	0,00	0,10	0,15	-0,01
	m29	29. I believe that more activities related to inspiration from nature should be included in curricula.	***0,85***	0,08	0,00	0,01	0,11	0,03
	m26	26. I would like to participate in training and courses on teaching inspiration from nature.	***0,81***	0,18	-0,06	0,05	0,13	-0,01
	m25	25. I believe that teachers need training on how to teach inspiration from nature to their students.	***0,75***	0,11	0,04	0,05	0,14	-0,06
	m31	31. I believe that students with lower academic achievement can learn better through activities inspired by nature.	***0,66***	0,07	0,01	0,02	0,13	0,12
	m22	22. I believe more training should be provided to teachers on how to teach inspiration from nature.	***0,42***	0,07	0,13	-0,03	-0,04	-0,08
2	m17	17. I can provide examples of five or more ideas inspired by nature.	0,19	***0,91***	-0,06	0,13	0,19	0,10
	m18	18. I can give examples of many devices and products developed by taking inspiration from nature.	0,19	***0,84***	-0,09	0,13	0,20	0,18
	m16	16. I can provide examples of five or more living beings that have inspired the design of a device.	0,17	***0,83***	-0,09	0,15	0,21	0,14
	m19	19. I can give more than three examples of methods I use to teach students how to develop creative thinking inspired by nature.	0,16	***0,69***	-0,12	0,22	0,26	0,29

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	m28	8. I can provide examples of scientists who have taken a high level of inspiration from nature in their inventions.	0,07	***0,44***	-0,18	0,16	0,18	0,16
3	m8	8. I am indifferent toward nature.	0,05	-0,16	***0,96***	-0,03	-0,06	0,00
	m9	9. I am indifferent to the structure and characteristics of most plants.	0,08	-0,21	***0,86***	0,00	-0,08	0,01
	m10	10. I am AFRAID of insects in nature.	0,00	-0,16	***0,80***	0,00	-0,06	0,04
	m11	11. I am indifferent to the structure and characteristics of most insects.	0,02	0,01	***0,60***	0,06	0,06	-0,02
4	m1	1. I can explain the concept of biomimicry with examples.	0,06	0,17	-0,01	***0,95***	0,09	0,08
	m2	2. I can explain the concept of biomimetics with examples.	0,02	0,18	-0,01	***0,95***	0,13	0,09
	m3	3. I can explain the small semantic differences between the concepts of biomimicry, biotechnology, bionics, biomimetics, and biomechanics.	0,08	0,23	-0,04	***0,84***	0,20	0,04
5	m5	5. I can effectively apply the process of designing an idea or product inspired by nature in my classroom.	0,21	0,23	-0,08	0,11	***0,80***	0,03
	m4	4. When I want to design a product, I can find an example in nature to take inspiration from.	0,17	0,28	-0,06	0,20	***0,62***	0,08
	m14	14. In my lessons, I regularly organize activities that encourage students to take inspiration from nature.	0,16	0,33	-0,07	0,20	***0,50***	0,22
	m7	7. I can effectively use strategies, methods, and techniques for teaching inspiration from nature.	0,26	0,26	-0,11	0,05	***0,49***	0,12
6	m23	23. I feel competent in teaching students how to take inspiration from nature.	-0,08	0,10	0,06	0,00	0,05	***0,75***
	m21	21. I believe that teachers' knowledge and skills in teaching inspiration from nature are sufficient.	-0,05	0,20	0,07	0,07	0,02	***0,66***
	m24	24. I believe that teachers are competent in providing students with examples of how to take inspiration from nature when designing an idea or product.	0,09	0,26	0,02	0,11	0,24	***0,57***
		Eigenvalue	8,21	3,89	2,96	2,05	1,29	1,24
		Explained Variance (%)	29,31	13,91	10,48	7,34	4,61	4,43
		Cronbach's Alpha	0,91	0,92	0,90	0,95	0,82	0,74

Examining Table 2, it is observed that the factor loadings of the scale items range between 0.44 and 0.96. The six identified factors were named as attitude toward teaching biomimicry, awareness of biomimicry applications, attitude toward nature, awareness of biomimicry concepts, self-assessment of biomimicry pedagogy, and self-efficacy in teaching biomimicry. The six-factor structure of the scale explains 70.08% of the total variance. Explaining more than half of the total variance indicates that the scale items have strong representational power. As a result, according to the EFA findings, the 27 items in the Biomimicry Teaching Self-Assessment Scale (BTsAS) were categorized under six factors. The variance explained by the six-factor structure is at a sufficient level. The calculated Cronbach's Alpha coefficients for the scale range between 0.95 and 0.74. These values demonstrate that the scale has high reliability based on internal consistency.

Confirmatory Factor Analysis Results

To test the six-factor structure of the Biomimicry Teaching Self-Assessment Scale (BTsAS), Confirmatory Factor Analysis (CFA) was conducted. This analysis allows us to assess the fit level of the six-factor structure using the obtained data. CFA was performed using the Maximum Likelihood Estimation (MLE) Technique, and goodness-of-fit indices were used to evaluate the model's alignment with the data. The detailed goodness-of-fit values are reported in Table 3.

Table 3. Fit Indices for the Six-Factor Structure of BTsAS

Fit Index	Good Fit	Acceptable Fit	Observed Values	Reference
(χ^2/sd)	≤ 3	$\leq 4\text{-}5$	3,12	Byrne, 1989
RMSEA	$\leq 0{,}05$	0,06-0,08	0,07	Browne & Cudeck, 1993
SRMR	$\leq 0{,}05$	0,06-0,08	0,06	
CFI	$\geq 0{,}95$	0,90-0,94	0,93	Bollen, 1989
TLI	$\geq 0{,}95$	0,90-0,94	0,92	
IFI	$\geq 0{,}95$	0,90-0,94	0,93	

Examining Table 3, it is observed that the six-factor structure of the Biomimicry Teaching Self-Assessment Scale (BTsAS) demonstrates an overall acceptable fit to the research data. The findings confirm that the six-factor structure of the scale is validated based on the research data. As a result of the Confirmatory Factor Analysis (CFA), the factor loadings of the items in the scale range between 0.41 and 0.98 (Figure 2). Additionally, it was observed that each path coefficient is statistically significant ($p < 0.01$).

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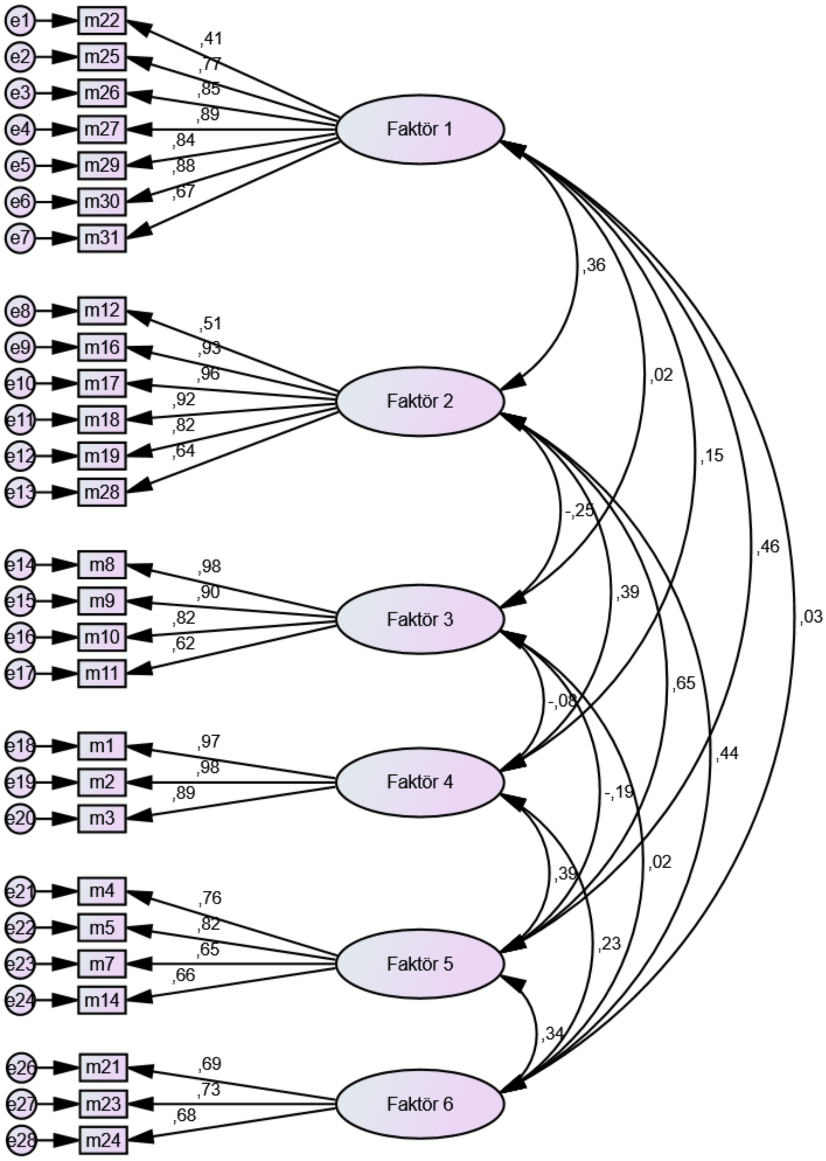

Figure 2. Confirmatory Factor Analysis Diagram (Chi-square = 962.77; df = 309; p < 0.001)

Discriminant Validity Analysis Results

An item analysis was conducted to examine the discriminative power of the Biomimicry Teaching Self-Assessment Scale (BTsAS) items. Accordingly, the total scores obtained from the scale were ranked in ascending order, and the top 27% and bottom 27% groups were identified.

In the next step, the scores obtained by these groups for each scale item were compared using an independent samples t-test. The obtained results are presented in Table 4.

Table 4. Discriminative Power of BTsAS Items

Item No	Bottom 27% Group (N=121)		Top 27% Group (N=121)		$t(240)$
	Mean	SD	Mean	SD	
m1	1,51	0,91	3,66	1,447	13,81***
m2	1,46	0,79	3,52	1,42	13,99***
m3	1,57	0,90	3,84	1,24	16,32***
m4	2,65	1,09	4,46	0,66	15,60***
m5	2,93	1,11	4,50	0,66	13,39***
m7	3,07	1,03	4,42	0,68	12,07***
m8	3,15	1,09	2,21	1,19	4,64***
m9	3,16	1,12	2,33	1,21	3,83***
m10	2,98	1,23	2,14	1,43	3,29***
m11	2,06	0,95	3,33	1,05	9,56***
m12	2,27	0,98	3,64	1,02	10,61***
m14	2,32	0,97	4,26	0,87	16,34***
m16	2,29	0,95	4,50	0,65	21,16***
m17	2,26	0,95	4,52	0,65	21,65***
m18	2,24	0,90	4,42	0,66	21,64***
m19	2,10	0,92	4,37	0,72	21,45***
m21	2,23	1,08	3,64	1,23	9,47***
m22	3,54	1,26	4,03	1,11	3,25***
m23	2,12	0,92	3,73	1,33	10,99***
m24	2,26	0,94	3,70	1,22	10,37***
m25	3,43	1,15	4,60	0,57	10,03***
m26	3,33	1,15	4,70	0,57	11,75***
m27	3,43	1,12	4,75	0,52	11,74***
m28	2,20	0,91	4,35	0,69	20,69***
m29	3,57	1,02	4,60	0,57	9,62***
m30	3,66	1,05	4,71	0,49	9,94***
m31	3,50	1,06	4,59	0,60	9,86***

***p<0,001

Examining Table 4, it is observed that the t-values for the items in the Biomimicry Teaching Self-Assessment Scale (BTsAS) are statistically significant ($p < 0.001$). The mean scores of the bottom 27% and top 27% groups indicate that, except for the reverse-coded items (m8, m9, and m10), the top group consistently scored higher than the bottom group. Overall, participants in the top 27% group obtained higher scores on scale items compared to those in the bottom 27% group. These findings confirm that each item in BTsAS is significantly discriminative.

Test-Retest Reliability Results

The Biomimicry Teaching Self-Assessment Scale (BTsAS) was administered twice to the same group with a two-week interval. The correlation coefficients between the scores from the two administrations were then calculated. These correlation coefficients were considered indicators of scale reliability. High correlation coefficients obtained from the test-retest method indicate stability between the two sets of scores (Tavşancıl, 2005).

The calculated correlation coefficients for this study are presented in Table 5.

Table 5. Pearson Correlation Coefficients Between Initial and Final Test Scores

Test	Application	N	Mean	SD	r
1. Attitude Toward Teaching Biomimicry	Initial Test	40	4,08	0,89	0,78*
	Final Test	40	4,21	0,96	
2. Awareness of Biomimicry Applications	Initial Test	40	3,32	0,80	0,72*
	Final Test	40	3,15	0,71	
3. Attitude Toward Nature	Initial Test	40	2,67	1,15	0,75*
	Final Test	40	2,86	1,24	
4. Awareness of Biomimicry Concepts	Initial Test	40	2,59	1,11	0,74*
	Final Test	40	2,79	1,26	
5. Self-Assessment of Biomimicry Pedagogy	Initial Test	40	3,52	0,89	0,72*
	Final Test	40	3,64	0,94	
6. Self-Efficacy in Teaching Biomimicry	Initial Test	40	2,95	1,12	0,79
	Final Test	40	2,93	1,15	
Total Score	Initial Test	40	3,18	0,99	0,83*
	Final Test	40	3, 26	1,03	

*p<0,05

Examining the table, it is observed that despite the time gap between the two administrations, the mean scores from the initial and final applications are very close to each other. The correlation coefficients between the subdimensions of the scale range between r = 0.72 and r = 0.79, while the overall scale correlation between the first and second applications is r = 0.83 ($p < 0.05$). These findings indicate that there are moderate to high-level relationships between the first and second test scores. The results confirm that the Biomimicry Teaching Self-Assessment Scale (BTsAS) has a stable measurement structure.

Criterion Validity Results

To establish the external validity of the Biomimicry Teaching Self-Assessment Scale (BTsAS), a criterion validity study was conducted by calculating the correlation between BTsAS scores and the Environmental Literacy Scale for Adults (ELSA) scores.

For this purpose, both scales were administered to participants in a single session. Subsequently, the relationships between the scores obtained from both scales were analyzed and examined (Table 6).

Table 6. Pearson Correlation Coefficients Between BTsAS Scores and Environmental Attitude Scale Scores

Variables	Environmental Literacy Scale for Adults (ELSA)
1. Attitude Toward Teaching Biomimicry	0,71**
2. Awareness of Biomimicry Applications	0,79**
3. Attitude Toward Nature	0,82**
4. Awareness of Biomimicry Concepts	0,75**
5. Self-Assessment of Biomimicry Pedagogy	0,69**
6. Self-Efficacy in Teaching Biomimicry	0,76**
Total Score	0,79**

** p<0,01; N=50

Examining the table, it is observed that there are strong positive correlations between the Environmental Literacy Scores and the subdimensions of the Biomimicry Teaching Self-Assessment Scale (BTsAS), with correlation coefficients ranging between $r = 0.71$ and $r = 0.76$. Additionally, a strong positive correlation was found between the total scores of both scales ($r = 0.79$, $p < 0.01$). These findings confirm that BTsAS demonstrates external validity, indicating that the scale effectively serves its intended purpose.

Conclusion, Discussion, and Recommendations

The research findings indicate that the sample size used for the validity and reliability analyses is highly compatible with factor analysis. According to the results of Bartlett's test of sphericity, there is a significant relationship among the variables ($\chi^2 = 9558.00$; $df = 351$; $p < 0.001$). These results confirm that the data set is suitable for factor analysis (Bartlett, 1937; Johnson & Wichern, 2002; Manly, 2005; Navarro, 2016).

In the factor analysis of the Biomimicry Teaching Self-Assessment Scale (BTsAS), six factors with eigenvalues greater than one emerged. The factor loading cutoff point was set at 0.40. According to Stevens (2012), items with factor loadings of 0.40 or higher make a significant contribution to the variance of the respective factor. Additionally, Yurt (2023) states that such factors contribute to a more realistic and meaningful analysis. The scree plot also shows a sharp decline after the seventh point. Parallel analysis further confirmed that the scale has a six-factor structure, validating the six-factor composition.

To further verify the identified factors, Confirmatory Factor Analysis (CFA) was conducted (Brown, 2015; Byrne, 2016; Hu & Bentler, 1999; Kline, 2015; Schreiber et al., 2006). The results of CFA confirmed that the items in BTsAS are significantly discriminative, supporting the validity of the scale.The Biomimicry Teaching Self-Assessment Scale (BTsAS) is divided into six factors: Attitude Toward Teaching Biomimicry, Awareness of Biomimicry Applications, Attitude Toward Nature, Awareness of Biomimicry Concepts, Self-Assessment of Biomimicry Pedagogy, and Self-Efficacy in Teaching Biomimicry.

The first subdimension of BTsAS is Attitude Toward Teaching Biomimicry. This dimension includes statements related to the necessity of integrating biomimicry into education, the need for biomimicry in teaching, the belief that students will learn better through biomimicry, teachers' willingness to participate in such courses, and the importance of biomimicry in education. Atabek-Yiğit et al. (2014) emphasize that teachers' motivation and attitudes play a critical role in helping students develop environmental literacy. According to Çoban and Coştu (2021), teachers who are sensitive to environmental and sustainability issues contribute to students developing positive attitudes toward nature. Kahyaoğlu (2011) also notes that teachers' attitudes significantly influence students' participation in nature-based activities and their level of environmental literacy. Based on these findings, when examining teachers' competencies in biomimicry education, their attitude toward biomimicry should be considered.

The second subdimension of BTsAS is Awareness of Biomimicry Applications. Nouri et al. (2021) state that teachers should recognize the importance of nature education and possess motivation for teaching. Benyus (1997), one of the first authors to write on biomimicry, aimed to raise awareness in this area. Çakır (2019) and Tavşan (2021) emphasize that teachers have low awareness of biomimicry education and that this should be improved. Çoban and Coştu (2021), Higgins and Nicol (2002), and Sandell et al. (2005) also highlight the importance of increasing teachers' awareness in this field. This subdimension includes statements related to how well teachers can explain and provide examples of biomimicry applications. Teachers should be able to integrate biomimicry into educational goals and effectively utilize their knowledge in this area (Turgut, 2011). Based on these findings, when evaluating teachers' competencies in biomimicry education, their awareness of biomimicry applications should be taken into account.

When it comes to teaching biomimicry, teachers' attitudes toward nature play a crucial role. The third subdimension of BTsAS focuses on recognizing nature and overcoming fear of nature. Rousseau (2010) emphasized that everything that does not originate from nature stands against it. Dewey, inspired by Rousseau's naturalist approach, encouraged experiential learning in nature (Bal, 1991). Atabek-Yiğit et al. (2014) and Tschannen-Moran & Woolfolk Hoy (2001) also stated that teachers should maintain a positive attitude toward nature. Furthermore, Kahyaoğlu (2011), Keleş et al. (2010), and Lugg & Slattery (2003) emphasized the importance of environmental attitudes and literacy in biomimicry teaching competencies. In this respect, the Attitude Toward Nature subdimension of the scale is a critical factor in evaluating teachers' biomimicry teaching skills. Based on these findings, when assessing teachers' biomimicry teaching competencies, their attitudes toward nature must be taken into account.

The fourth subdimension of BTsAS evaluates teachers' understanding of biomimicry concepts, definitions, and distinguishing similar terms. In their teacher competency model, Blömeke & Delaney (2012) define cognitive abilities as including "what" and "how" knowledge. Shulman (1986) emphasizes pedagogical content knowledge, while Schwartz & Lederman (2002) highlight the role of general pedagogical knowledge. Abd-El-Khalick (2013) stresses the significance of pedagogical content knowledge in biomimicry teaching. Similarly, Nouri et al. (2021) state that teachers must possess subject knowledge and scientific literacy to prevent misconceptions. Atabek-Yiğit et al. (2014) also argue that teachers must be familiar with biomimicry terms, concepts, and definitions. However, research suggests that many teachers lack a deep understanding of biomimicry or hold misconceptions about it (Bartos & Lederman, 2014; Davis & Smithey, 2009; McComas & Clough, 2020). Therefore, this subdimension of the scale plays a crucial role in assessing teachers' awareness of biomimicry concepts. Based on these findings, biomimicry concept awareness should be considered when evaluating teachers' biomimicry teaching competencies.

The fifth subdimension of BTsAS focuses on teachers' perceptions of biomimicry teaching strategies, methods, and techniques. Teachers must possess general pedagogical knowledge and be able to integrate it with biomimicry education. Tschannen-Moran & Woolfolk Hoy (2001) argue that teachers should not only have pedagogical content knowledge but also instructional strategies and assessment knowledge. Abd-El-Khalick (2014) emphasizes that teachers' self-efficacy in biomimicry pedagogy should be strengthened, and they should gain practical experience in this process. Cebrián & Junyent (2015) suggest that teachers must develop competencies in knowledge, practical skills, ethical values, attitudes, and emotions. Based on these findings, when evaluating teachers' biomimicry teaching competencies, their self-assessment of biomimicry pedagogy should be taken into account.

The sixth subdimension assesses teachers' perceived self-efficacy in biomimicry teaching. This factor evaluates teachers' knowledge and skills in biomimicry, their competence in delivering biomimicry education, and their confidence in handling biomimicry-related content in instructional settings. According to Nouri et al. (2021), teachers should be able to design and modify appropriate tools and methods for evaluating biomimicry teaching applications. Tschannen-Moran & Woolfolk Hoy (2001) highlight the significance of self-efficacy in biomimicry teaching, while Atabek-Yiğit et al. (2014) emphasize that teachers need high self-efficacy levels for effective environmental literacy instruction. Lee & Witz (2009) state that high self-efficacy levels are critical for the effective implementation of biomimicry pedagogy. Based on these findings, when evaluating teachers' biomimicry teaching competencies, their self-efficacy perceptions should be considered.

The six-factor structure of BTsAS explains 70.08% of the total variance. Explaining more than half of the total variance indicates that the scale items have strong representative power (Brown, 2015; Byrne, 2016; Hu & Bentler, 1999; Kline, 2015; Schreiber et al., 2006). In conclusion, based on EFA and CFA results, the 27 items of BTsAS provide an adequate variance explanation for the six-factor structure. The Cronbach's Alpha reliability coefficients calculated for BTsAS range between 0.95 and 0.74. According to DeVellis (2016) and Nunnally & Bernstein (1994), reliability values above 0.70 are considered good, while values above 0.90 are considered very good. Based on these criteria, the obtained values indicate that BTsAS has high internal consistency reliability.

To assess the reliability of BTsAS, the test-retest method was employed. This method evaluates the stability and reliability of the scale over time. The high correlation coefficients obtained through test-retest analysis demonstrate the consistency of scores over different applications, confirming the stability of BTsAS. To establish the external validity of BTsAS, a criterion validity study was conducted by calculating the correlation between BTsAS scores and the Adult Environmental Literacy Scale (AELS) scores. Criterion validity assesses the degree to which a measurement tool accurately reflects the intended construct by comparing it with a relevant criterion (Cohen & Swerlik, 2018; Nunnally & Bernstein, 1994; Tavşancıl, 2005). The results indicate strong positive correlations between BTsAS sub-dimensions ($r = 0.71 - 0.76$) and overall score ($r = 0.79$, $p < 0.01$), confirming that BTsAS meets external validity standards and serves its intended purpose.

In conclusion, the validity and reliability analyses of BTsAS confirm its strong alignment with factor analysis, demonstrating its suitability for factor-based assessment. The six-factor structure is appropriate for evaluating teachers' self-assessment of their biomimicry teaching competencies. The scale exhibits high internal consistency, and test-retest results further confirm its stability over time. The criterion validity study establishes strong positive relationships between BTsAS scores and related measures, reinforcing the scale's ability to fulfill its intended purpose. Given these properties, BTsAS serves as a reliable and valid tool for assessing teachers' self-efficacy in biomimicry education and can be effectively used to evaluate teachers' self-assessments in biomimicry instruction.

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