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Research Article / Araştırma Makalesi

Biomimicry for a Sustainable Future: A Qualitative Study Based on Expectancy Theory

Fevziye Bekar [a]

ABSTRACT

Purpose – The aim of this research is to examine how biomimicry education, which is an important applied field in terms of sustainability, is experienced and interpreted by university students studying management information systems and software engineering within the framework of expectation theory.

Design/data/methodology – In the first phase of the research, students were educated on the field of biomimicry within the context of a STEM-based programme. In the second phase, students were asked to develop ideas inspired by nature; these ideas were shared with primary and secondary school students within the scope of TÜBİTAK Science Talks. Eight months after the educational process, interviews were conducted to evaluate participants' expectations and experiences regarding sustainability. The study employed a phenomenological framework to conduct in-depth qualitative research, using semi-structured questions based on expectation theory.

Findings – Biomimicry training has supported the development of creativity. However, the ideas developed after the training could not be implemented. It is believed that individuals need to be included in the entrepreneurial ecosystem in order to meet expectations in this process. Moreover, it has been found that sustainability-related studies are more beneficial when carried out in close contact with nature and as a team.

Originality/value – The original value of this research consists in examining biomimicry education in technology-focused disciplines within the framework of Expectancy Theory and evaluating its long-term effects using a phenomenological approach. Furthermore, the fact that students pass on their nature-inspired ideas to younger generations through social interaction adds a different value to the study.

Keywords: Sustainability, Biomimicry, Expectancy theory

Sürdürülebilir Bir Gelecek için Biyomimikri: Beklenti Teorisi Temelinde Nitel Bir Araştırma

ÖZET

Amaç – Bu araştırmanın amacı, sürdürülebilirlik açısından önemli bir uygulama alanı olan biyomimikri eğitiminin, yönetim bilişim sistemleri ve yazılım mühendisliği alanlarında öğrenim gören üniversite öğrencileri tarafından beklenti kuramı çerçevesinde nasıl deneyimlendiğini ve anlamlandırıldığını incelemektir.

Tasarım/veri/metodoloji – Araştırmanın ilk aşamasında, STEM temelli bir program kapsamında öğrencilere biyomimikri konusu üzerine eğitim verilmiştir. İkinci aşamada, öğrencilerden doğadan ilham alan fikirler geliştirmeleri istenmiş; üretilen bu fikirler TÜBİTAK Bilim Söyleşileri kapsamında ilkokul ve lise öğrencileriyle paylaşılmıştır. Eğitim sürecinden sekiz ay sonra gerçekleştirilen görüşmelerde, katılımcıların sürdürülebilirlik alanına ilişkin beklenti ve deneyimleri değerlendirilmiştir. Çalışmada, beklenti kuramı temel alınarak öğrencilere yarı yapılandırılmış sorular yöneltilmiş ve süreç, fenomenoloji deseni çerçevesinde nitel araştırma yöntemiyle derinlemesine incelenmiştir.

Bulgular – Biyomimikri eğitimi yaratıcılığın gelişmesi konusunda destek sağlamıştır. Fakat eğitim sonrası geliştirilen fikirler hayata geçirilememiştir. Bu süreçteki beklentilerin karşılanması için bireylerin girişimcilik ekosistemine dahil edilmesinin gerekli olduğu düşünülmektedir. Üstelik, sürdürülebilirlik ile ilgili çalışmaların doğa ile iç içe, ekip halinde sürdürülmesinin daha faydalı olacağı bulgulanmıştır.

Özgünlük/değer – Bu araştırmanın özgün değeri, teknoloji odaklı disiplinlerde biyomimikri eğitiminin Beklenti Kuramı çerçevesinde incelenmesi ve uzun vadeli etkilerinin fenomenolojik yaklaşımla değerlendirilmesidir. Ayrıca, öğrencilerin doğadan ilham alan fikirlerini toplumsal etkileşim yoluyla genç kuşaklara aktarması çalışmaya farklı bir değer katmaktadır.

Anahtar Kelimeler: Sürdürülebilirlik, Biyomimikri, Beklenti kuramı

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[a] Gümüşhane Üniversitesi, fevziye.gurlas@gumushane.edu.tr, Gümüşhane, Türkiye;
Sorumlu Yazar: Fevziye Bekar, fevziye.gurlas@gumushane.edu.tr

1. Introduction

According to the report titled "Sustainable Signals: Individual Investors", prepared by the Morgan Stanley Institute, 70–90% of individual investors stated that sustainability practices are important when making investment decisions in companies (Morgan Stanley, 2025). From the perspective of social sciences and organizational behavior, sustainability implementation processes require a holistic approach that includes the development of mental competencies, the preparation of educational environments, and the motivation and expectation-based decision-making processes of participants (Robbins & Judge, 2019).

Biomimicry, which refers to the development of technologies inspired by nature (Benyus, 2002), offers important application-based tools for sustainability (Zhang et al., 2025). One of the most fundamental examples of biomimicry is Velcro fastening strips. Swiss engineer George de Mestral invented Velcro after studying the hooked structure of burdock burrs that clung to his dog's fur (Benyus, 2002).

The microstructure of the lotus flower, which repels water and dirt from its surface, has inspired the development of self-cleaning paints and glass (Barthlott & Neinhuis, 1997). Similarly, new generations of climbing robots and adhesives have been developed based on the microscopic hairs covering the feet of gecko lizards (Autumn, 2000). Such examples can be multiplied. Biomimicry education offers significant opportunities to enhance creativity within individual and institutional processes in engineering, architecture, and design (Yen & Weissburg, 2016).

Although this issue has been frequently examined in the field of educational sciences (e.g., Kopman & Porfiri, 2012; Yıldırım, 2019; Avcı, 2019; Türe, 2023; Ergül, 2023; Adıgüzel et al., 2024), research on value-based knowledge that strengthens individuals' expectations and motivation, including those in the social sciences, remains limited. Moreover, such research also contributes to students' career development. Within this scope, the present research aims to examine in depth the motivation, expectations, reward perceptions, and performance of students in the management information systems and software engineering departments based on biomimicry education, drawing on Vroom's expectancy theory, which holds a significant place among motivation theories. This focus is particularly important because the concept of biomimicry may initially appear highly abstract at the individual cognitive level. Such abstraction can hinder the development of application-based processes in this field.

This research seeks to answer the question: *"How do university students in software engineering and management information systems departments experience and make sense of biomimicry education within the framework of expectancy theory in relation to their motivation, expectations, and decision-making?"* Expectancy theory posits that individuals' behaviour is

shaped by the perceived likelihood that their effort will lead to successful performance (expectancy), the personal value they assign to the anticipated outcomes (valence), and the perceived relationship between performance and those outcomes (instrumentality) (Vroom, 1964; Lunenburg, 2011).

Based on this fundamental assumption, nine questions were prepared, and the research was designed using a qualitative methodology. Initially, workshops were developed as part of a year-long STEM-based application that incorporated biomimicry and included idea-development processes. STEM is an educational approach that integrates the disciplines of science, technology, engineering, and mathematics, emphasizing hands-on, application-oriented learning. STEM education aims to cultivate 21st-century skills in students, such as critical thinking, problem solving, creativity, and collaboration (Bybee, 2010; Xie, Fang, & Shauman, 2015; Yıldırım, 2016). The present study was shaped by the experiences and observations gathered during the year following the completion of the workshop. It is intended to serve as a foundation for academics and practitioners seeking to further advance research and practice in this area.

The existing literature largely focuses on the technical outcomes and competency development associated with technology-related education (Reap, 2010; Yen & Weissburg, 2016). In contrast, this research addresses psychological and behavioural dimensions, including how technology can be developed in harmony with nature by considering natural working principles, as well as the motivational processes and reward perceptions of trainees. This focus is important because there is a notable gap in the literature on these aspects. Moreover, for effective twin transformation processes, it is essential to understand this domain, in which individuals exhibit innovative thinking and sustainability-oriented approaches (Shalley et al., 2004; Wigfield & Eccles, 2000). Accordingly, this study, grounded in expectancy theory, examines biomimicry applications within the social sciences and organisational behaviour fields. It is expected to fill a significant gap by addressing the motivational dynamics of trainees in the context of twin transformation within digital transformation processes. In doing so, it offers a unique perspective for those developing educational programmes in this area, human resources specialists, and professionals interested in enhancing sustainability and technology-based motivation.

2. Literature Review

According to The Turkish Language Association (Türk Dil Kurumu), sustainability is defined as *"the state of being sustainable*." Sustainable development was addressed within the framework of sustainability through the *Our Common Future* Brundtland Report prepared in 1987 by the World Commission on Environment and Development (WCED). Sustainable development is defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Şen, Kaya, &

Alpaslan, 2018). One of the fundamental processes hindering sustainability is the lack of awareness about how nature works (Orr, 1992). This understanding can lead humans to destroy their own basic sources of life and sustenance by acting on an instinct to dominate everything. As a result, the depletion of natural resources, one of the fundamental factors of sustainable development, brings about social and economic losses. This situation stems from the fact that the close connection between human habitats and the ecological environment is often overlooked. There are two ways to fundamentally resolve this issue: either to distance ourselves from nature and wait for it to renew itself as it has done for centuries, or to understand how nature works and integrate this knowledge into our lives, educational processes and production models. The second approach offers a much more effective and holistic approach to sustainable development. In this context, Janine Benyus's (1998; 2002) book Biomimicry: Innovation Inspired by Nature marked a significant turning point in the development of the field of biomimicry. Benyus states that nature has produced sustainable and efficient solutions over billions of years of evolution; therefore, it functions almost like a vast research laboratory. From this perspective, humans can develop more efficient technologies—both economically and environmentally—by learning from nature, thereby advancing more effectively toward sustainable development goals. In short, achieving future-oriented sustainable development objectives and establishing a sustainable economy require embracing ecological thinking, that is, learning to act in cooperation with ecological systems and shaping our ways of living based on this understanding (*see*, McMichael, 2004). Benyus (1997) laid the foundations of the biomimicry discipline by emphasizing that nature offers a production model that aligns precisely with these criteria.

According to Raman et al. (2024), biomimicry holds substantial potential for addressing sustainable development goals. Biomimicry, derived from the combination of *bio* (life) and *mimicry* (imitation), applies nature's patterns and strategies to address human problems, contributing to the Sustainable Development Goals by fostering innovative and sustainable solutions (Raman et. al. 2024). Extensive research on biomimicry has since been conducted across various fields, including architecture (Metwally, 2025), ocean studies (Hasan et al., 2024), robotics (Tan et al., 2025), and education (Yıldırım, 2019). For example, El-Zeiny (2012) emphasises that it is necessary to go beyond the superficial imitation of forms found in nature, stating that true biomimicry requires the integration of biological processes, systems and organisational principles into the design process. According to the research, the biomimicry approach offers a powerful methodological framework for developing sustainability, energy efficiency, and user-centred solutions in interior design. The author also states that treating nature as a model, benchmark and mentor enables designers to produce more innovative and sustainable solutions to the spatial problems they encounter (El-Zeiny, 2012). Amer (2019) examined

biomimicry education among 18 architecture students and investigated its contribution to sustainability-oriented design processes. The study found that biomimicry increased students' awareness and strengthened their design abilities. Similarly, Canbazoğlu Bilici et al. (2021) integrated biomimicry into environmental education courses for middle school students by assigning an eco-friendly engineering design task focused on air pollution. In this activity, the locomotion systems of grasshoppers, ants, spiders, and red Japanese beetles were used as biological models. Through this biomimicry-based approach, students explored a range of living organisms, and this experience was shown to support the development of new STEM-based technological products. Raman et al. (2024) conducted a systematic review that presents a comprehensive roadmap and demonstrates the relationship between biomimicry and sustainable development.

Examples can be multiplied. But most research in the field is related to environmental education and the production of robotic products inspired by nature. However, no research has been found that examines individuals' expectations regarding biomimicry based on engineering and management information systems programmes, linking them to motivation theories and examining them. Based on the gap encountered in the application-based education process and reflected in the existing literature, this study conducted research grounded in expectancy theory. Expectancy theory was developed by Victor Vroom in 1964 (İlgün, 2010 as cited in Akduman & Taşdelen, 2021). Vroom's Expectancy Theory explains individual motivation through three fundamental factors: Expectancy (belief that effort will lead to performance), instrumentality (belief that performance will lead to specific outcomes), and valence (the value that the outcome holds for the individual) (Koçel, 2020). According to Koçel (2020), expectancy theory emphasizes that the primary factor guiding individuals' behavior is their cognitive assessment of how their efforts will translate into outcomes. In this regard, the theory explains that motivation in learning processes is shaped by the individual's perceived probability of success and the benefits that this success is expected to provide. Within the context of this study, students' belief that biomimicry education contributes to their innovative thinking, sustainable design, and problem-solving skills is considered a key factor shaping their learning motivation. When students perceive nature-inspired design processes as valuable both for enhancing their performance and for supporting their future professional development, they are likely to engage in learning efforts at a higher level. Therefore, expectancy theory is regarded as an appropriate and explanatory theoretical framework for understanding the motivational dynamics of students within biomimicry-based educational settings.

Thus, there is also no evidence of any work that enables students in the field of education to contribute to society by passing on the issue they have learnt about biomimicry to others, thereby spreading a culture of sustainability. Therefore, the

originality of this research lies in the integration of ecological thought processes within management information systems and software engineering disciplines through expectancy theory, its long-term analytical perspective, and its inclusion of the social transfer dimension of sustainability. These aspects are addressed in greater detail in the research methodology.

3. Method

The study was conducted using a phenomenological research design, a qualitative approach aimed at exploring participants' lived experiences. Phenomenology focuses on understanding individuals' lived experiences of a particular phenomenon and the meanings they attribute to these experiences (Yıldırım & Şimşek, 2021). In this research, the phenomenon under examination is biomimicry. The study investigated the experiences of management information systems and software engineering students who received biomimicry education, as well as their motivational processes shaped by their identified goals. In other words, the phenomenological design was selected to gain an in-depth understanding of the meanings students derived from their biomimicry learning experiences and how these experiences influenced their personal expectancy.

The sample for the study consists of volunteer management information systems and software engineering students who began biomimicry training in July–August 2022–2023 academic year. The study was developed based on problems experienced during a process carried out within the scope of TUBITAK-2209-A student projects. The project planned to conduct face-to-face training and workshops with 20 volunteer students. Announcements were made regarding participation in the training. Twelve students indicated their intention to participate in the training, but only 10 students attended regularly. The 6 February Kahramanmaraş earthquake was a significant factor in the participation not reaching the expected level. Therefore, instead of the face-to-face module, the training process was started online, and various difficulties were encountered throughout the project. In addition, two students withdrew from the process on the grounds that the course did not meet their expectations, while some students had difficulty relating the subject to their own fields. For these reasons, the aim of the research focused on examining the process based on expectation theory.

Nine months after the workshop was completed, interviews were conducted with seven students who had participated in the course. The participants were selected using the maximum variation sampling method, which is commonly employed in qualitative research to include individuals with diverse characteristics in order to examine the phenomenon from multiple perspectives and identify common themes (Patton, 2014). Accordingly, students differing in gender, age, academic

achievement levels, and motivational backgrounds were included in the study. Creswell (2018) suggests that phenomenological research typically involves between 5 and 25 participants. In line with this recommendation, the inclusion of seven participants was deemed sufficient to explore the phenomenon in depth.

Two of the participants were third-year students and five were fourth-year students; four were enrolled in the Management Information Systems department and three in the Software Engineering department. Of the seven participants, four were female and three were male, with a mean age of 22.14.

3.1. Research Design and Process

In the first phase of the research, a one-month biomimicry training programme was implemented. Following this training, two-hour weekly meetings were held for two months to support the development of students' project ideas. During the training period, the students' ideas were both exhibited and introduced within the context of the biomimicry discipline. In the final stage, participants had the opportunity to share the knowledge they had gained with primary and secondary school students through TUBITAK Science Talks. After these stages, a semi-structured interview form based on the training process was developed, and interviews were conducted to determine the students' expectations and to reveal their reflections on the overall experience. The interviews lasted between 10 and 15 minutes, and a total of seven students were interviewed. All interviews were transcribed verbatim using the Transkriptor tool.

The following questions were asked during the interview process.

Research Question 1: Were you able to relate your personal goals to your biomimicry training goals?

Research Question 2: When you relate biomimicry applications to your field, how do you evaluate application-based processes?

Research Question 3: When you reflect on the effort, time, and energy you invested in the workshop process, do you feel that this education was worthwhile for you? Why?

Research Question 4: What positive and negative outcomes did you experience during and after the training process?

Research Question 5: How did you experience the value of the outputs you achieved, and what kinds of benefits did they provide for you?

Research Question 6: What suggestions do you have for improving the training based on your experiences during the process?

Research Question 7: How do you perceive the relationship between your performance in the course and potential rewards, and what expectations do you hold in this regard?

Research Question 8: Have the rewards offered so far been meaningful to you? What kinds of rewards would you prefer?

3.2. Data Analysis

The data analysis process was conducted using MAXQDA 2020 software. Participant views were converted into themes based on each question, and frequency distributions were calculated. In the analysis, the open coding method was used to review the open-ended data obtained from semi-structured interviews, and meaningful words and phrases were converted into codes (Strauss & Corbin, 1998; Saldaña, 2021). Subsequently, in the axial coding stage, codes with similar meanings were combined, and cause-effect relationships between concepts were determined (Boeije, 2010; Charmaz, 2014). Thus, the data were organised into a holistic structure in line with the theoretical framework.

3.3. Validity and Reliability

To ensure methodological rigour in the research, the eight-step protocol proposed by Creswell and Creswell (2021: 200–201) was applied. This framework offers various strategies for ensuring reliability and validity in qualitative research. Accordingly, long-term interaction was established with participants, and detailed and rich descriptions were made to increase the credibility of the findings. Data obtained from different stages of the study were compared to ensure triangulation; verifiability was strengthened through expert opinion and peer review. Participants' statements were confirmed through member checking, and any conflicting situations regarding the process were reported transparently. A detailed audit trail was maintained throughout the research, and transferability was enhanced by providing detailed contextual information. Thus, the validity and reliability of the research were ensured by systematically applying eight steps, and the robustness of the findings was reinforced.

4. Findings

Research Question 1: Were you able to relate your personal goals to your biomimicry educational goals?

Participants reported that they did not combine their personal goals with the biomimicry areas P2 and P7.

P2: I couldn't relate biomimicry to my personal goals, so I cannot say that it benefited me directly. However, in terms of idea formation, it provided me with a new perspective. I can say that.

P7: I couldn't relate them, but if I wanted to, I could. I could find a way. I wouldn't relate it myself. Because my field is software, and frankly, I don't want to move to a department that's very much related to mechatronics.

P1, P3, P4, P5, and P6 stated that they related their personal goals to the objectives of biomimicry education.

P1: Yes.

P3: My personal goal is to reach a very high level in the field of software engineering. I now clearly recognize this as my desire and ambition. I have always been able to understand computers better than people, which is why I want to attain a strong position in terms of both

technical knowledge and vision. The biomimicry training opened a slightly different window for me in this regard. It showed me that taking inspiration from nature and developing innovative solutions can make my approach to problem-solving in software more creative. Although not directly, I can say that it connected to my goals indirectly by influencing my way of thinking

P4: I haven't entered the workforce yet, but I mentioned that I have applied biomimicry in the projects we have completed so far. It is certainly relevant in my field, because we also develop technology by taking inspiration from nature. In this way, we are able to solve certain problems in the physical technologies we develop by using biomimicry.

P5: Yes, applying biomimicry in software projects was truly valuable. As I mentioned, there are many aspects of nature that can inspire algorithm development, data management, or even design elements such as colour and selection. These examples help us build more efficient systems. For this reason, I find biomimicry quite functional in practical processes.

P6: Actually, yes, I did relate it. In terms of its usefulness, I was able to connect it to the projects we completed, the lessons we covered.

In light of this information, the summarised responses organised by theme are presented in Table 1.

Table 1. The Combination of Personal Objectives and Biomimicry Educational Objectives

Sub-theme	Participant(s)	Code Number	Percentage
Inability to establish relationships	P2, P7	2	22,22
Gaining a creative/different perspective	P3, P5	2	22,22
Project and implementation experience	P4, P6	2	22,22
Contribution to professional and personal development	P3, P5	2	22,22
Problem solving and innovative approach	P5	1	11,2

Research question 2: When you relate biomimicry applications to your field, how do you evaluate application-based processes?

Participants responded to this question as follows:

P2: First of all, when I joined this project, I didn't have much knowledge. It was my first time participating in a project, and I was responsible for its implementation. Naturally, certain expectations were placed on me. Although it was challenging at first to meet these expectations, I improved myself over time. These expectations actually had a positive impact on my development. They pushed me to grow, learn, and conduct research. For example, while I initially thought of simply asking someone else for help, I eventually strengthened my own research skills.

P6: We first gained foundational knowledge on the subject, and then we developed a project related to biomimicry. That was how I made the connection. In other words, after learning about the topic, we applied what we had learned through the project work.

Research Question 3: When you reflect on the effort, time, and energy you invested in the workshop process, do you feel that this education was worthwhile for you? Why?

All researchers answered yes to this question. Sample statements from the researchers are provided below.

P1: Yes.

P2: Yes, this was definitely a very effective approach. Without it, we would have begun the

process with far less knowledge. Initially, training on self-awareness was provided, followed by explanations and examples related to biomimicry. This was genuinely helpful and effective, and it enabled us to understand and internalize the subject much more thoroughly.

P3: I think it was worth it. At first, it felt a bit complicated and unfamiliar, but as we progressed and I understood the philosophy behind it, I found myself thinking, 'I'm glad I participated.' I believe this type of education is necessary for everyone. For me, this understanding alone is already a meaningful gain. Even if I had not learned anything else, acquiring this perspective would have been sufficient.

P4: Honestly, it was well worth the effort we put in. Because, as I mentioned, we were developing projects during our very busy classes at the time. We gained different perspectives on how to develop these projects.

P5: Yes, it was worth it, although there were moments when I struggled. Due to the overall workload, it sometimes became quite overwhelming. However, the workshop sessions were definitely worthwhile. The ideas that emerged made all the effort worthwhile.

P6: Of course, I think it was worth it. From a social perspective, going out and giving presentations was very beneficial for me.

Research question 4: What positive and negative outcomes did you experience during and after the training process?

Based on this question, participants reported their positive and negative views. Below is information about the participants' positive views:

P1: I had expectations for a positive outcome, and it met them.

P2: As a positive outcome, we gained a better understanding of the concept of biomimicry, learned more about it, and actually learned how to draw inspiration from nature to solve problems in our daily lives as a result of this work. For example, I can mention the concept of widespread impact. We gave training sessions and seminars in the places we visited, and this actually developed us very well. It enabled us to improve ourselves in terms of explaining things and explaining a subject we know about. We also actually imparted a lot of information to other students. We enabled them to gain a perspective in this field. We can say these are positive. There isn't much I can say was negative... What could this add to me? What will I learn here? What could I do? Or, am I doing this for nothing? Now I'm going to spend time on it, but is it pointless, what is this? I thought, will it just stay on paper, will it just be online meetings? But the opposite happened. We actually went to the university and carried out various activities. I tried speaking as a presenter; I was nervous at first. It didn't go well the first time, but it did the second time. We were working as a group, and being part of that group helped me represent myself and take a more active role. These were positive experiences for me.

P3: The positive aspect, as I mentioned earlier, is that even if there is no connection whatsoever, it definitely helped change the way I think. It made me realise that I can draw innovation ideas from nature.

P5: The positive aspect, is that, as I said, my perspective has changed. Whereas I used to think of nature as the enemy of technology, I now started to look at technological problems from the perspective of finding solutions using examples from living things in nature or from nature itself.

P6: The positive outcome is that I learned something new and realized that progress can be made in the field of technology. I also gained knowledge about this subject.

Participants reported the following views regarding the negative aspects of

the training:

P3: The negative aspect was that sometimes the subject felt too theoretical. Since the education was delivered in an online, distance-learning format, the concepts remained somewhat abstract, and we found it challenging to apply the theory in practice. Had the education not been conducted as distance learning, I believe the practical application process would have been less of an obstacle.

P4: The negative aspect was that the training created an additional workload for the participants. This challenge did not arise from the content or structure of the training itself but from the fact that it overlapped with a period of heavy course load. Balancing the demands of regular coursework with the additional training required considerable effort. Nevertheless, these difficulties were eventually addressed and managed by the participants.

P5: On the negative side, sometimes the deadlines were very short, and everything piled up due to the intensity. At that point, I began to feel somewhat overwhelmed. I reduced my sleep, and certain areas were not progressing as productively as before. However, despite these challenges, the process was eventually managed.

P6: The negative aspects also occurred over a long period of time. The intervals were long. I am a bit impatient in that regard, and I wanted to complete things immediately. Since this was my first project, I was very excited and eager for everything to happen right away. That was the only negative aspect for me.

Table 2. Information regarding positive and negative opinions based on education

Sub-theme	Participant(s)	Code Number	Percentage
Positive Comments			
Change in perspective / innovative thinking	P3, P5	2	33,3
Personal and professional development	P1, P2, P6	3	50,0
Increased motivation and participation	P1	1	16,7
Total		6	100
Negative Comments			
Remaining theoretical / lack of application	P3	1	25,0
Time management and workload issues	P4, P5	2	50,0
Gaps in the process / impatience	P6	1	25,0
Total		4	100

Research question 5: How did you experience the value of the outputs you achieved, and what kinds of benefits did they provide for you?

Information about the value judgements of the participants is presented below.

P2: In terms of its broader impact, I can say that it benefited us by giving us the opportunity to speak in front of a community and present information. This helped us develop ourselves in that direction. As a value, it introduced biomimicry into our lives and encouraged us to think with that mindset. In that sense, it provided us with a new perspective.

P3: The outcomes showed me something important. Developing technology is not only about writing code—at least for me. It also involves asking the right questions, finding the right answers, and recognizing that many solutions already exist in nature. It is about producing creative and insightful approaches to problems. I believe this experience provided me with a valuable perspective as I progressed in software engineering.

P4: When a person has a clear goal, certain sacrifices may become necessary. This can involve setting aside aspects of social life, leisure, or holidays—not because these are unimportant, but because progress sometimes requires prioritizing long-term aspirations over short-term comfort.

P6: It was very beneficial to me in terms of research. It was also beneficial in terms of the project. At least I had a project that I could put on my CV or mention and talk about.

P7: The productivity process... It was formed at the idea stage. I was able to relate my thinking a little more to nature. Before, I just... I would say nature is nature and leave it at that, but after this process, when I think about any idea or project, I can now incorporate technologies derived from nature into it. I can blend them together and form a thought, come up with an idea.

Table 3. Themes based on the combination of personal objectives and biomimicry educational objectives

Sub-theme	Participant(s)	Code Number	Percentage
Widespread impact and social contribution	P2	1	14,3
Creative and innovative perspective	P2, P3, P7	3	42,9
Creating value through effort and dedication	P4	1	14,3
Academic and professional development / CV contribution	P2, P6	2	28,6
Total		7	100

Research question 6: What suggestions do you have for improving the training based on your experiences during the process?

Participants offered the following suggestions.

P2: It could have been different in some ways. For example, we never really went out into nature—at least not in a way that was integrated into the training. Although we received the content, I feel that delivering the programme face-to-face rather than online would have been more effective. Conducting parts of the training directly in nature might sound a bit unusual, but I believe it could have created a stronger impact. Beyond simply thinking about nature, actually experiencing it might have deepened our understanding, since we are already part of it. Such an approach could have been beneficial, although its absence did not create a major issue.

P5: First, if the trainees' schedules and the overall programme are planned effectively, additional workshops could be incorporated. However, without proper planning, increasing the workshop frequency might have the opposite effect and create unnecessary pressure. Apart from this, seeing biomimicry examples that are more directly connected to technology projects would be particularly inspiring.

P7: Actually, I think that here, rather than working individually, it was necessary to produce something through teamwork.

Research Question 7: How do you perceive the relationship between your performance in the course and potential rewards, and what expectations do you hold in this regard?

Below are the participants' views on their expectations of rewards based on the biomimicry training process:

P1: Not in the form of material rewards, but yes—there were motivating elements. Supportive and encouraging feedback was given throughout the process, and I realised that this made me feel genuinely appreciated. Such positive reinforcement can also be considered a form of reward. I noticed that hearing those encouraging comments had a strong motivational effect on me.

P2: Actually, as with any work, when we do something, receiving a reward makes us feel more motivated. We received gifts as a result. Our gifts were notebooks and pen sets. They were nice, with a personalised design. That was good, it felt good. It increased our motivation. As for what else could have been done... I never thought about that.

P3: No, because I think learning is one of the greatest rewards in a person's life.

P4: It's not something we could expect a reward for, but no one was expecting you to give us money there anyway, but I mean... I don't know, like a certificate or something, we could congratulate these people for achieving this. I mean, logically, other students could expect a certificate or something, personally.

P5: No, sir, I didn't expect a reward. It would be encouraging if the work done were visible, for example, a project presentation or a certificate.

P6: No, I didn't actually expect any reward. The gift given at the TUBITAK Science Talks, the gift presented at the dean's office with the department chair... I wasn't really expecting the gift given there. I honestly wasn't expecting it at all. It was actually a very happy thing for me.

P7: No, I didn't.

Research Question 8: Have the rewards offered so far been meaningful to you? What kinds of rewards would you prefer?

Participants shared the following views on the subject of rewards:

P1: We went out for fish, we went for a walk. These are very motivating things. We socialise, you know. We share things outside of the training. It requires more commitment, it makes us take our work more seriously. It's good that these things happen. I mean, the meal was nice.

Social activities such as having dinner together could also be considered. It was enjoyable to work with the department head and the Dean's Office as well. When I think about it now, informal moments—like having tea together—are what stay in my mind the most. Formal interactions with lecturers are easy to forget because they follow a certain structure, but activities such as shared meals, conversations, or trips create a more relaxed atmosphere. These more social and comfortable settings tend to be more memorable.

P2: The most motivating aspect for me was not the reward itself. What truly made me feel valued was being guided by a more experienced and knowledgeable academician, and having the outcome of the course formally documented in the Dean's Office together with the department chair. It was also the first time we had the opportunity to speak directly with our professor, and this made us feel acknowledged. The fact that our project was taken seriously, evaluated by an expert academic, and officially recorded significantly increased my motivation. Therefore, for me, the most important thing was not a tangible reward but having my effort recognised and appreciated.

P3: For me, rewards are more future-oriented. In my view, success itself is one of the most meaningful forms of reward. If this process opens new opportunities, contributes to my personal or professional development, or allows me to meet new people, that is what I consider a true reward. In other words, the most valuable outcome is not a tangible incentive, but the progress and possibilities that emerge.

P5: No, I did not have any expectations of a reward. Simply seeing the outcome of the work,

such as presenting a project or receiving a certificate, is already encouraging for me.

P7: Since I did not expect any reward, anything I received felt like a bonus, to be honest. Whether it was a notebook or something personalised with my name on it, I simply saw these as extra bonuses… Instead of receiving a notebook or a book on biomimicry, the reward could have been something different. I don't think we live in an age where people still read books extensively. Yes, younger children may read books for their development, but in my opinion, our generation learns more effectively through research rather than traditional reading. For this reason, a different type of reward could have been offered—such as tablets or computers. Beyond material rewards, opportunities could also have been provided, such as attending a conference as participants or representing the team at career events in different cities. Rewards of this kind would have felt more meaningful and aligned with our current learning and professional development needs.

5. Discussion

This research was planned to be conducted in 2022 with 20 volunteer students. The aim was to provide biomimicry training to 20 students and continue the process with idea development workshops. There were some difficulties in selecting volunteer students. This was because the students did not initially want to participate in the training. Some even started the training but then wanted to leave, stating that they would not engage with the field. Secondly, this process coincided with the Kahramanmaraş earthquake on 6 February 2023. In addition to the earthquake causing destructive and extensive damage, very few students could be reached. The earthquake was an unforeseen situation for us, and therefore we were unable to prevent the challenges that emerged regarding participant engagement. Since the process relied on voluntary participation, we did not want to create any form of coercive influence or place additional expectations on the students. Given the sensitivity of the circumstances, we also aimed to avoid causing anyone psychological distress.

Despite these challenges, we strived to navigate and complete the earthquake-related state of emergency as effectively as possible. So, the training process was negatively affected from the participants' perspective. Four of the students involved in the project were part of the project team, while the others participated at the request of their academic advisors at the university. The project was completed with 10 students. Although the earthquake process showed us how important it is to be in harmony with nature, it was observed that university students did not want to receive education outside of academic units. It was experienced that the social environment and power of the project advisor are important in such important educational organisation processes.

Most participants found the training processes beneficial and stated that biomimicry training was a skill-enhancing element that increased creativity and offered problem-solving methods. In this project, unlike other biomimicry training programmes, students also took on the role of educators through TUBITAK Science Talks. That is As part of biomimicry education, during the TUBITAK Science Talks, school administrators

who were visited were asked to allow time for students receiving biomimicry education to share their experiences. Within this scope, two separate sessions were conducted—one for secondary school students and one for high school students. During the high school session, students directed most of their questions to the university students rather than the academics, showing particular interest in their departmental experiences. They explained that they felt more comfortable communicating with university students and could ask questions more freely, without the perceived bureaucratic distance often associated with academic staff. Within this scope, it was found that the inclusion of university students in science talks was a motivating factor for students in their careers. This also contributed to the development of their social and cognitive competencies. The developmental role of biomimicry in this regard is consistent with findings in the literature (Benyus, 2002; Yen & Weissburg, 2016; Bar-Cohen, 2012).

The first question asked whether students could establish a relationship between their personal goals and biomimicry goals. Here, it was observed that establishing this relationship led to high motivation in terms of valence and expectancy. When this connection is weak, participants' education-based motivation may also decrease (Lunenburg, 2011). In a discipline such as biomimicry, which aims to produce innovation inspired by nature, the alignment of participants' fields with educational plans is an important element in the educational design process and participants' careers.

The second question aimed to obtain information based on participants' processes of relating biomimicry to the fields of management information systems and software engineering. As biomimicry is a relatively unknown field, students may experience negative emotions such as insufficient knowledge, uncertainty, and lack of self-confidence. Supportive learning environments can motivate researchers to increase their desire to learn, take responsibility, and develop themselves (Deci & Ryan, 2000; Freeman et al., 2014; Schunk and DiBenedetto, 2020). P2 stated that he had high expectations of himself and that this contributed to his development. This situation has shown that the pressure process supports development (Vroom, 1964). K6 stated that he developed the project after acquiring knowledge. This situation points to the instrumental dimension between performance (learning/research) and reward (project success, satisfaction). Although such training programmes may be challenging for participants at the outset, appropriate support and opportunities can increase motivation. These opportunities may be based on appreciation that supports participants, relying on moral rather than material factors (Deci and Ryan, 2000).

In the third question, most participants stated that although it was a challenging process, participating in this research was worth the effort. However, some participants mentioned difficulties encountered during the training. Here, due to the academic intensity, the training was challenging in terms of certain issues being difficult and

participants experiencing problems in finding ideas. Despite this difficulty, the reason they continued with the project was that their efforts were rewarded with a noticeable increase in performance and positive results. It was emphasised that although there were short-term difficulties, the process was valuable in the long term. In the literature, this situation can be explained by the interpretation of difficulty and the reward expectation balance (Vroom, 1964; Park, 2010).

Within the scope of the fourth question, participants were asked to report on the positive and negative aspects of their education-based expectations. According to the responses obtained here, positive feedback was received regarding gaining different perspectives and personal and professional development issues (Illeris, 2018). These feedbacks are consistent with the findings in the literature. At the same time, the sharing of scientific literacy with social groups in terms of social contribution is also considered a positive aspect for the participants. However, the participants reported that the education process was too theoretical regarding the issue. This indicates difficulties, especially based on the field of work. The fact that individuals did not have a process focused solely on this training, but also had elements such as continuing academic advancement, was an important issue that increased stress among participants. These stress processes can negatively affect success and academic progress (García-Martínez et al., 2021). Consequently, while biomimicry training increases motivation in terms of both individual and social outcomes and meets expectations, issues such as lack of application, time management, and overly dense content must be taken into consideration.

The fifth question concerned explaining individual motivation through the components of expectation, instrumentalism, and value. This question sought to understand what kind of value judgement was formed in individuals. According to the findings of the research, most participants found the outcomes they achieved to be valuable in personal and academic terms. It was stated that gains such as presentation, project development, and innovative thinking were important. These processes contributed to the participants' curriculum vitae (CVs), allowed them to experience social contribution, and helped them develop disciplined work behaviours. Challenges such as leading a project for the first time or initially lacking sufficient knowledge were gradually overcome and transformed into high performance. This outcome illustrates that high expectations shape the relationship between effort and performance (Wigfield & Ponnock, 2020). Factors like enhancing one's CV represent tangible rewards, whereas the learning experience itself functions as an intrinsic reward—aligning with findings that intrinsic values often take precedence in voluntary education processes (Ryan & Deci, 2017). Overall, these findings indicate that the meaning and perceived value of a reward may differ from one individual to another.

This training was originally planned to be conducted in person, but due to the earthquake, it was carried out online. This situation was considered unfavourable by the participants. Participants indicated that face-to-face and team-based work could be important in this field (Garris & Fleck, 2022). Another factor mentioned was that nature-related training could be beneficial when conducted in close contact with nature (Kuo, Barnes & Jordan, 2022). The training process may have fallen short of meeting students' expectations. This situation indicates that participants had high expectations of benefit and success; however, factors such as the undesirable nature of the online environment, the inability to plan due to extraordinary circumstances, and the intense workshop pace could negatively affect motivation. A value- and application-oriented approach could be a factor that enhances learning quality and participant motivation (Bond et al., 2020).

Most participants stated that they did not expect a reward for their performance in the course and that the abstract elements (learning, self-improvement) were the main reward. In addition to this, they stated that concrete gifts (certificates, events, etc.) were an extra motivating factor. It was noted that, as we live in an age of technology, more high-quality rewards such as computers and tablets could also be given.

During the course, participants were presented with personalised pens and notebooks, as well as a book on biomimicry, as gifts. In addition, upon completion of the project, a meeting was held with the Dean of the Faculty of Economics and Administrative Sciences and the Chair of the Management Information Systems Department at the dean's office to express appreciation for the participants' contributions. Within the scope of TÜBİTAK Science Talks, educational sessions were conducted in two different districts. In these sessions, not only the project advisor but also the students who participated in the project were given the opportunity to take on the role of speakers and deliver training activities.

For the participants, the most memorable aspect of the process was the social engagement component. Taking on an educational role and contributing to the learning of others had a stronger and more lasting impact. In contrast, bureaucratic processes were less memorable, whereas sincere and interactive environments left a greater impression. Overall, activities that participants could personally relate to and attribute meaning to were found to have a greater impact on volunteers throughout the project. Therefore, it has been found that assigning students the role of educators is an important component of this type of education-based project, and existing opportunities can be effectively utilized in this regard.

6. Conclusion

This research was conducted to qualitatively explore how STEM-based biomimicry education is experienced and interpreted by management information systems and software engineering students in relation to their value perceptions, academic

development, and performance processes within the framework of expectancy theory. The findings suggest that experience-based biomimicry education, including practices grounded in nature, is perceived by students as supporting creativity and contributing to the development of problem-solving and communication skills.

In recent years, natural disasters, particularly COVID-19 and earthquakes, have clearly demonstrated the importance of understanding nature's vital processes and adopting an environmentally conscious mindset. The more people we can convey this mindset to, the greater our contribution to sustainability will be. Biomimicry is one of the important tools for making this contribution. However, difficulties have been encountered in advancing this education process, which is based on voluntary participation. Contrary to expectations, it has not been possible to reach more students; participation has mostly been limited to social networks and advisor support. This situation has demonstrated how critical the influence of the project advisor is. Furthermore, it has been understood that in the context of sustainability efforts in Turkey, not only voluntarism but also obligations will play an important role. Making courses on sustainability issues compulsory at universities could ensure more effective participation in the process, both due to students' expectations of passing the course and performance-based motivation.

It is crucial that sustainability education is supported not only by theory but also by practice-based activities. However, many ideas that have been developed cannot be implemented due to a lack of adequate support mechanisms. Therefore, establishing a sustainable entrepreneurship ecosystem and developing perspectives based on this ecosystem is considered a critical necessity that will provide lasting and effective contributions for both students and society.

This research has unique value in the theoretical context in that it demonstrates the applicability of Vroom's expectancy theory in the biomimicry education process. Here, it has been revealed that participants' motivation can be influenced by the effort-performance link, the performance-reward link, and the personal meaning of the reward. It is emphasised that the internal (learning, self-development) and external (certificate, gift, recognition) motivations of individuals who voluntarily participate in the process will create differences, and that reward systems can be personalised based on the trainees. Furthermore, it has been determined that in interdisciplinary education processes, progressing in a way that develops application-based, social, and cognitive skills within the framework of contributing to society has long-term positive results. Looking to the future, this research can be restructured using goal-setting theory and social network theories.

This study is expected to provide important insights for human resources management, experts, educational institutions, and researchers seeking to develop sustainable, innovative, and personalised education models.

Finally, it should be reiterated that sustainability should be made a way of life rather than a voluntary act. It should be combined with elements that can make people's expectations attractive. Otherwise, we will continue to progress towards a life spent in pursuit of short-term gains, failing to learn from the negative events we experience as a society. We will continue to suffer heavy losses and endure processes that add pain upon pain.

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Conflict of interest

The author declares that there are no potential conficts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Ethics committee approval was received from Gümüşhane University Scientific Ethics Approval Board with the number E-95674917-108.99-282478 on 20.09.2024.

In this research, limited support from the artificial intelligence tools ChatGPT and Deeply was used for translating participant statements into English, improving the linguistic quality of the texts, and checking reference consistency. Artificial intelligence was not used for content generation or data production; all findings, analyses, and interpretations were conducted solely by the author. In accordance with ethical principles, AI tools were utilized only for linguistic refinement and reference verification.

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ORCID

[a] Fevziye Bekar, http://orcid.org/0000-0003-1692-4294

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