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The Awareness of Biomimicry Among Secondary School Students

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Abstract

Natural harmony and functioning have always attracted the attention of people. Humans have imitated systems and mechanisms of nature in many different fields such as technologyand health. The concept of biomimicry stands out in the search for more efficient use of natural resources, sustainability and solutions from nature. The current study aims at determining the secondary school students' knowledge and awareness towards biomimicry. The case study method was employed and 50 studentsat different grade levelsfrom a rural secondary school in the Central Black Sea Region of Turkey were participated in the study. The data were collectedby survey and interview form developed by the authors. The survey consists of 23 questions and three dimensions namely, science-technology-research relationships, nature-to-design solutions and linking design with nature. A semi-structured interview sheet was also prepared consisting of seven questions about biomimicry awareness. Descriptive and procedural statistics were applied to the data using the SPSS program. We found outthatstudents had a moderate level of science-technology perception and biomimicry awareness. Significant gender-related and grade level-related differences were obtained in different dimensions. Some suggestions were made based on the findings.

Keywords: Biomimicry, science education, secondary school students, science teaching, nature to design.

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Introduction

All processes in nature have been running smoothly for thousands of years without any human intervention. On the other hand, we are increasingly able to explore nature's 3.8 billion years of experience using our current tools and capabilities (Ginsberg, Schiano, Kramer&Alleyne, 2013, Karabetça, 2018; Volstad& Boks, 2012;). Today, the importance is given to energy efficiency and sustainability, and similar concepts indicate the necessity of returning to our essence, namely, to nature. Benyus (1997) defines biomimicry as a new branch of science that examines, imitates, and inspires models in nature to find solutions to human problems. Biomimicry is the inspiration and imitation of entities in nature to create new designs (Benyus, 2002).Benyus, in his work entitled "*Biomimicry: InnovationInspiredby Nature*" examined the transfer of information to products and argued that nature has features that can be used in many fields for humanity. On the other hand, Gardner (2012) defines biomimicry as the reverse engineering of identifying problems, finding suitable solutions for these problems in nature, and redesigning these solutions for the benefit of humanity. From such a perspective, biomimicry establishes a relationship between engineering and science disciplines. Simply put, biomimicry is defined as "a creative form of technology that uses or imitates nature to improve human life" beyond simply imitating life (Hwang et al., 2015, p.5701). With biomimicry, not only the solutions developed by nature, but also systems, mechanisms, and design strategies are taken as the basis. Today, the biomimicry process is carried out bybeing inspired by a structure, form, or an entire ecosystem (URL -1,2020; Inner, 2019).

Janine Benyus made a great contribution to introducing the concept of biomimicry into the literature towards the end of the 20th century. The aim of using depleting natural resources more efficiently has increased the popularity of this concept recently. The main purpose of biomimicry is to produce more with less. Some examples from nature can be given for this tremendous economy: the information storage capacity of the DNA helix; the ability of birds, bees, ants, and turtles to navigate and fly without using any tools; the ability of dragonflies to maneuver better than a helicopter; the adhesion strength of mussels to rocks. Besides, many engineering products are designed using the biomimicry approach. For example, adhesives for microelectronics and space exploration studies were developed based on the sticky property of lizard feet; lamps, lenses, phone screens, touch screens, and anti-reflection/anti-glare films were made todevelopeon the anti-reflective and sight-facilitating nano-structures in the eyes of insects that can fly at night (URL-2, 2019). Within the same concept,submarines were developed based on the structure of dolphin and shark skin (URL-2, 2019; Mahgoub&Alawad, 2014). Furthermore,the bumpy structures on the leaves of the lotus plant allow the water to slide over the leaves in the form of droplets. Using this feature of the plant, self-cleaning surfaces were produced (Yıldız, 2012).Velcro strap was invented based on the thorny seeds that stick to the trousers while walking in the field (URL-2, 2019), Inspired by the movements of the tuna tail, tribunes that generate electricity from underwater currents were developed (Boga-Akyol & Timur-Ogut, 2016). Moreover,solar energy panelsinspired by sunflowers and treepods inspired by trees are the most beautiful and interesting examples of the use of biomimicry (URL-1, 2020).

Biomimicry has also been widely used in architecture and design. Producing sustainable, energy-efficient, waste-free, and recyclable designs by applying the principles of nature can be recognized as the use of biomimicry approach in different areas of life. There are two different approaches in biomimicry practices, from biology to design and from design to biology. The biology-to-design approach is about examining the characteristics and functioning of a biological organism or ecosystem and taking it as an example for the solution of the design problem. The design-to-biology approach, on the other hand, is solving a defined design problem by examining how organisms and ecosystems in nature perform this function (Peters, 2011). According to Panchuk (2006), the biology-to-design approach is non straight forward, whereas thedesign-to-biology is a straight-forward approach.

A literature survey revealed that there were few studies on biomimicry in the field of education. Some of these studies can be summarized as follows: Subsoontornark (2018) conducted a workshop on the use of biomimicry based on STEM (an approach that integrates science, mathematics, technology and engineering disciplines). Kim (2019) developed a biomimicry-based instructional design for technology education.Sanne, Risheim, and Impelluso (2019) designed a

teaching activity to help students gain an understanding of biomimicry. Yakisan and Velioğlu (2019) analyzed 4th grade students' drawings for their biomimicry perceptions. Alperen (2020) developed a STEM-based instructional design (Nature-inspired technologies) for the 5th grade science applications course and examined its implementation process. Yıldırım (2019) examined pre-service science teachers' views on biomimicry practices in STEM education. The Green Education Foundation (GEF) was designed an instruction that aims to give students the ability to imitate nature(URL-3,2019). Avcı (2019) performed the document analysis of studies on biomimicry between 1997-2019 in his study entitled"nature and innovation: biomimicry in schools". Ersanlı (2016) examined the importance of biomimicry in physics education.

To the best of our knowledge, no study has examined the awareness of biomimicry among secondary school students despite the increasing attention for biomimicry. Therefore, the current paper aims at identifying secondary school students' awareness of biomimicry.

Method

The case study method was utilized in this study. The case study is a method in which a limited sample and multiple data collection tools are used to comprehensivelydescribe a specific phenomenon (Creswell, 2009; Şimsek, 2012). A case study is a "qualitative approach in which the researcher collects detailed and in-depth information about real life, a current limited situation, or multiple constrained systems (situations) in a given time, through multiple sources of information" (such as observations, interviews, documents and reports), and makes a situation description (Creswell, 2013). This research is a case study since it is tried to determine the knowledge and awareness of secondary school students about biomimicry through questionnaires and interview questions.

Sample

The sample for this study consists of rural secondary school children located in the Central Black Sea Region of Turkey, in the fall semester of the 2021-2022 academic year. Among 58 students in the school, those who did not fully answer the questions and were not present at school on the day of the implementation did not participate in the study. The distribution of the sample by gender and grade level is given in Table 1.

Table 1. The Distribution of the Sample by Gender and Grade Level

	5th grade		6th grade		7th grade		8th grade	
	n	%	n	%	n	%	n	%
Female	6	54.54	3	42.86	14	58.33	5	62.5
Male	5	45.46	4	57.14	10	41.67	3	37.5

A total of 50 students (26 girls and 22 boys) joined in the study. In the sample, 11 students were 5th graders, 7 students were 6th graders, 28 students were 7th graders, and finally, 8 students were 8th graders.According to the results of the survey, a total of 7 students were interviewed, selected from the students with the highest scores from each grade level.

Data Collection Tools

A survey was designed consisting of open-ended questions to determine secondary school students' knowledge and awareness of biomimicry.For preparing the survey, visuals obtained from websites (URL- 1, URL- 2, URL- 4) about biomimicry were used. The survey comprises three parts. The first part consists of 4 questions about demographic characteristics and science-technology-research relationships. In the second part (inspires from nature to design part), the relationship between honeycomb and telescope design was explained as an example. Then, visuals and features related to biomimicry were given to the students and they were asked to choose which design used this relationship. In the third section (links from design to nature part), some designs were shown to the students and they were asked to state which phenomena/things in nature were similar to these designs. The first, second, and third sections consist of 4, 9 and 10 questions, respectively. The validity of the surveywasdetermined by receivingopinions of two faculty members who are experts in science education and another faculty member who is an expert in biology. In addition, a pilot study was

performed with a secondary school student from a different school. Furthermore, a semi-structured interview sheet was prepared and interviews were conducted with the selected students. The semi-structured interview sheet consists 7 questions. In the interview, the students were asked questions about their awareness of biomimicry, the sources they researched, and whether they were interested in this field.

Analysis of Data

The answers given by the students to the survey were subjected to descriptive analysis. Incorrect or blank answers were scored as zero, acceptable answers as 1, and completely correct answers were scored as 2.5. Such a scoring method was preferred to score a completelycorrect answer higher than two partially correct answers (Kaya, 2005). The frequency and percentage values of all questions are presented in tables. We also checked whether the total scores were normally distributed. The skewness and kurtosis coefficients of the total scores were calculated as -0.19 and -0.48, respectively. Since these values were between -1 and +1, the data were decided to be normally distributed.Proceduralstatistics were conducted using the SPSS program. Unrelated samples t-test among parametric tests, Man Witney U and Kruskal-Wallis H tests among nonparametric tests were performed. To evaluate the reliability of the analyzes, the coding made by two independent researchers was compared and the Miles Huberman (1994) inter-coder reliability was calculated as 0.89.While making quotes from the answers given to the survey, the students were coded as S_1, S_2, ...The interviewed students were coded as K_1, K_2, ...The interviews were descriptively analyzed and the results were shown with graphs and diagrams.

Findings

The frequency distribution of the secondary school students' answers to the survey is given in Table 2. In the Table, the first four questions measure the science-technology-research relationships, questions 5-13 measure nature-to-design practices, and the remaining questions were about reflections of designs in nature.

Table 2. Descriptive Analysis of the Biomimicry Survey

		Wrong (0)		Acceptable (1)		Completelytrue (2.5)			
		n	%	n	%	n	%	$\bar{x}$	s
Science-technology-researchrelationship (STRR)	Q1	25	50	23	46	2	4	0.56	0.63
	Q2	28	56	19	38	3	6	0.53	0.69
	Q3	31	62	13	26	6	12	0.56	0.84
	Q4	18	36	17	34	15	30	1.09	1.02
Inspiresfromnaturetodesign (INtoD)	Q5	36	72	14	28	-	-	0.28	0.45
	Q6	25	50	18	36	7	14	0.71	0.86
	Q7	15	30	2	4	33	66	1.69	1.15
	Q8	37	74	10	20	3	6	0.35	0.68
	Q9	19	38	19	38	12	24	0.98	0.96
	Q10	34	68	11	22	5	10	0.47	0.79
	Q11	23	46	7	14	20	40	1.14	1.17
	Q12	9	18	8	16	33	66	1.81	1.01
	Q13	27	54	22	44	1	2	0.49	0.57
Links fromdesigntonature (LDtoN)	Q14	43	86	3	6	4	8	0.26	0.71
	Q15	24	48	1	2	25	50	1.27	1.25
	Q16	20	40	20	40	10	20	0.90	0.93
	Q17	18	36	2	4	30	60	1.54	1.20
	Q18	24	48	4	8	22	44	1.18	1.21
	Q19	38	76	10	20	2	4	0.30	0.61
	Q20	32	64	14	28	4	8	0.48	0.75
	Q21	12	24	1	2	37	74	1.87	1.08
	Q22	35	70	13	26	2	4	0.36	0.62
	Q23	10	20	2	4	38	76	1.94	1.02

According to the answers of the student, questions 7, 12, 17, 21, and 23 had a higher rate of correct answers. On the other hand, more than 50% of the students gave wrong answers to questions 2,

3, 5, 8, 10, 13, 14, 19, 20 and 22. According to the mean scores; the mean scores of questions 7, 12, 21, and 23 were close to 2, which was between acceptable and completely true.In the second section, the mean scores of the 7th question "While walking in nature, in a field or a garden, you may have seen cockleburs stuck to your clothes. What product inspired by these cockleburs, which stick to clothes or animal hairs with their thorns?" and 12th question "Dragonflies cannot fold their wings over themselves. Also, their flight muscles move the wings differently from other insects. Because of these characteristics, dragonflies are recognized as"primitive insects" according to evolutionists. However, the flight system of dragonflies, defined as "primitive insects", is a marvel of design. Which product could have been designed based on the flight system of dragonflies?" were higher. In the third section that asking what the source of inspirations in nature for 21-Mini robots and 23-Scuba diving flippers are were highest mean scores. The total survey mean score and standard deviation were calculated as 0.90 and 0.55, respectively. Considering the acceptable level was 1 and completely true was 2.5, the students' awareness of biomimicry was found to be below moderate.

In the section about science-technology-research relationships, the students mostly linked science with research. For example, the student S_1explained science saying "The results obtained by research are called science". On the other hand, we observed that some students created visual images about science despite they did not have detailed knowledge about science. The answer given by the student $S_{21}$was attention-grabbing, "When we talk about science, I think of bubbling red bubbles in bottles". This answer was evaluated as wrong in the scoring stage. Among the acceptable answers in this section, the comment of the studentS_{10},"Science is researching anything that is curious and discovered" can be considered as an example.Also, among the answers given to the question "How could scientists' studies of living and non-living things in nature affect their work? Could it have influenced creativity and imagination?",the answers that associate science with imagination draw attention. The answer of the studentS_{32} "Yes, probably. Being curious, creative, and dreamer are already among the characteristics of a scientist." was considered true. The answer of the student $S_7$for the same question, "It may have influenced them to make inventions by being inspired by some living things." was considered acceptable. An answer that is considered incorrect was the response of the student S_{28}"In my opinion, it's very pointless that everything is running with electric".

In the inspires from nature-to-design part, the students were shown some images from nature, and they were informed about these images and asked to state possible technological designs that may be associated with them. Among the answers given in this section, it was noteworthy that the students easily establish the relationship between the products they encounter in their daily life and the sources of inspiration in nature for these products. For instance, in response to the image about a dragonfly, most of the students stated helicopter and some stated helicopter and drone. These answers were considered true. For the same question, student S_{26}responded "This could be the rudder of a ship". However, this answer was considered wrong. On the other hand, the student S_{40}commented as "Airplane" and this answer was considered acceptable.

In the design-to-nature part of the survey, the students were shown some images about designs inspired by nature and were asked to state their opinions about possible connections of these designs with nature. Answers of some students are presented here. For example, a bionic arm image was shown to the students and they were asked to associate this design with something in nature. The studentS_{33}replied to this question saying "Elephant trunk, octopus arm" and this answer was considered true. The student S_{49}commented "It looks like tail of animals" and this answer was considered acceptable. On the other hand, the S_{14}answered the same question saying "Snake, worm"; however, this answer was considered wrong.

The comparison of the students' biomimicry survey scores according to their gender was examined with the independent samples t-test. The results are shown in Table 3.

Table 3. Comparison of the Survey Scores according to Gender

	Gender	n	$\bar{X}$	s	df	t	p
STRR	Female	28	3.34	2.28	48	2.470	0.017*
	Male	22	1.97	1.56			
INtoD	Female	28	7.68	4.70	48	-0.455	0.651

	Male	22	8.23	3.54			
LDtoN	Female	28	10.71	4.85	48	1.043	0.302
	Male	22	9.32	4.49			
Total	Female	28	21.73	9.69	48	0.893	0.37
	Male	22	19.52	7.20			

According to the t-test results given in Table 3, total survey, nature-to-design and design-to-nature scores did not significantly differ by gender (p>0.05).On the other hand, science-technology-research relationships scores significantly differed in favor of female students (t_{48}=2.470; p=0.017)

To compare the students' scores according to grade level, we decided to use non-parametric tests.If there are more than two groups in a variable, one-factor ANOVA among parametric tests is appropriate. To perform one-factor variance analysis, the data should be normally distributed, each group should consist of at least 15 subjects, and group variances should be equal (Büyüköztürk, 2007). Therefore, the Kruskal-Wallis H test was performed to compare student groups with different grade levels.To find source of variance between groups, each pair of groups was compared with the Mann Whitney U test. Descriptive statistics regarding grade level are given in Table 4. Table 5 shows the results of the H test.

Table 4. Distribution of the scores according to grade level

		STRR		INtoD		LDtoN		Total	
Grade	N	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
5th	11	2.33	2.11	5.63	3.29	7.18	4.72	15.18	8.64
6th	7	1.50	1.38	6.86	4.30	9.00	3.52	17.36	7.36
7th	24	3.45	2.12	9.90	3.88	11.71	4.83	25.06	7.82
8th	8	2.18	1.51	6.06	3.95	10.25	3.48	18.50	6.55
Total	50	2.74	2.03	7.92	4.19	10.10	4.70	20.76	8.67

Table 5. Comparison of the Scores according to Grade Level

			STRR		INtoD		LDtoN		Total	
Grade	N	sd	MeanRank	X^2 *p*	MeanRank	X^2 *p*	MeanRank	X^2 *p*	MeanRank	X^2 *p*
5th	11	3	22.82	6.205	17.32	10.530	16.82	8.519	16.82	11.959
6th	7		16.79	0.102	21.43	0.015*	20.86	0.036*	19.21	0.008*
7th	24		30.444		32.33		31.29		32.79	
8th	8		22.00		19.81		24.13		21.06	
Total	50									

According to the mean ranks, the mean rank of the 7th graders was the highest and 5th graders was the lowest. The difference between mean ranks were found to be significant [($X^2_{(3-50)}$= 10.530 p<0.05; $X^2_{(3-50)}$=8.519 p<0.05;$X^2_{(3-50)}$=11.959, p<0.05]. The source of variance was examined and the difference in total scores between 5th-7th grades (U=50.50; p=0.004), between 6th-7th grades (U=39.00; p=0.033), and between 6th-8th grades (U=47.50; p=0.035) were found to be significant.On the other hand, the differences in the nature-to-design scores between5th-7th grades (U=52.00; p=0.004) and7th-8th grades (U=46.50; p=0.029) were determined as significant. And the difference in the design-to-nature scores between 5th-7th grades (U=59.00; p=0.008) was significant.

To obtain more insight into students' awareness of biomimicry, interviews were conducted with students who received high scores from the survey at each grade level. The obtained data by the interviews are shown in the graph (Fig. 1). The interviewed students were coded as K_1, K_2, ... K_{10}.

In the interviews, the students were asked whether they have heard about the concept of biomimicry, whether they noticed similarities between designs and nature, make research on these

topics, they are interested in these topics and want to participate in projects and research.

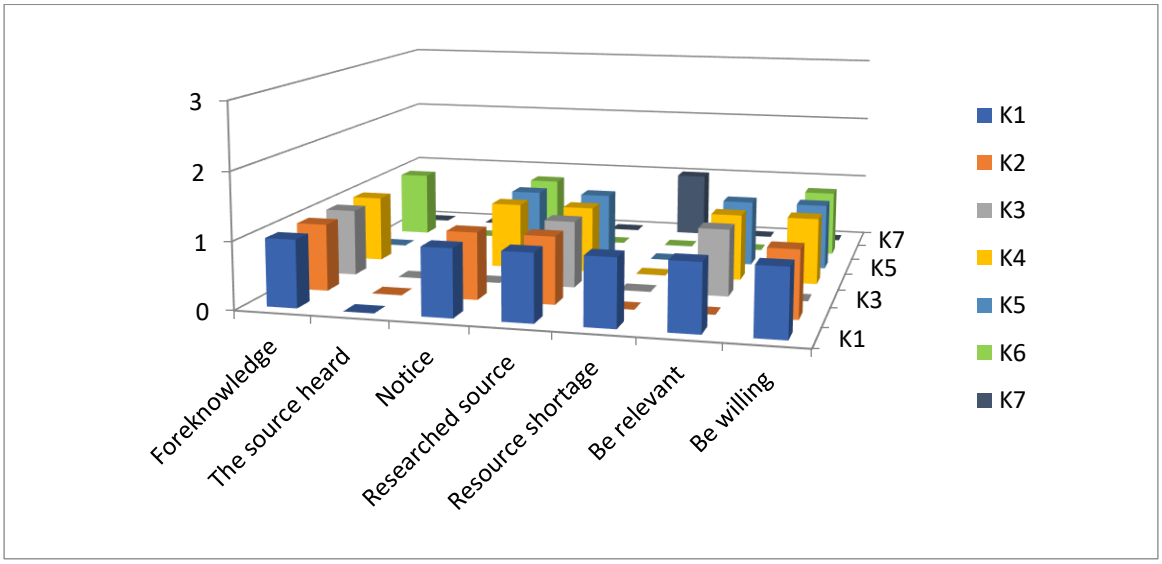

Figure 1. Analysis of answers to interview questions

As seen in Figure 1, the obtained data indicated that some students did not hear about biomimicry before this study.However, the students could not clearly state the place where they heard this concept. Although studentK_5did not hear about this concept before, she stated that she noticed some design examples inspired by nature.Moreover, the same student indicated that she researched this similarity but did not encounter the concept of biomimicry. Another issue about student comments worth noting was research sources. The students $K_1$and K_7stated that they didn't know where to search for these subjects and that they had difficulties in finding sources. Another noteworthy finding from interviews was that some students were not interested in biomimicry. A majority of the students stated that they were willing to participate in research and projects on biomimicry. Surprisingly, the students $K_2$and K_6also stated they were not interested in this topic. On the other hand, student K_7stated that he was not interested in these subjects and was not willing to participate in research and projects.

A more detailed analysis of students' comments is shown in Figure 2.

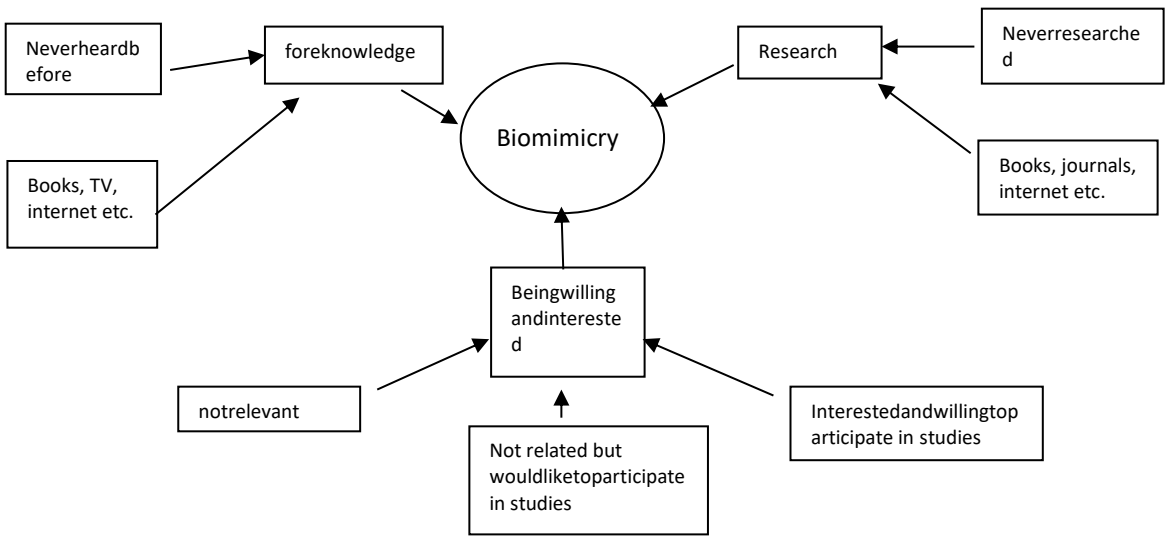

Figure 2. Schematic representation of interview data

As shown in Figure 2, some students stated they did not hear the concept of biomimicry before. The students who have heard this concept were stated that they heard it from TV, books, and the internet. Another topic given in the scheme was the sources used by students to search biomimicry. Similarly, the internet stands out for making research. The answer of the student $K_1$is noteworthy. This student stated that the internet sources are not reliable so, she had difficulties in doing research and finding sources.We obtained that the students can be examined under three groups regarding biomimicry. These are those who were not interested in biomimicry, those who were not interested but willing to participate in studies on this topic, and those who wereinterested and willing to participate in studies.

Discussion and Conclusion

Our findingsrevealed that secondary school students had a low level of knowledge about science-technology-research relationships.The first part of the survey consists of questions about science-technology-research relationships. The total ratio of acceptable and completely true answers was below the ratio of wrong answers (Table 2). It can be argued that students did not completely understand that science is developed through research and accordingly, technology advances. Although there was no clear and sharp definition of science and technology, a majority of the students think that the scientists' examination of the things in nature affects their imagination and creativity (question 4).In a study carried out by Hastürk, Öztürk, Demir, andKartal (2014), in response to the question “What is science?”, 40% of primary school students chose the option “To explore the unknown about our world and the universe, to discover new things and how they work”, while 48% of secondary school students said, “Finding and using the necessary information (such as curing diseases, analyzing pollution and improving agriculture) to make this world a better place for life”. In the same study, it was found out that 49% of primary school students and 45% of secondary school students believe that scientist uses their imaginations while planning and interpreting their studies.Accordingly, it can be argued that secondary school students’ views about imagination and creativity in science are consistent with the current study.Çetinkaya (2019)conducted a study involving 6th grade students and examined students' definitions of science before and after education on the nature of science. The students considered experiments and research as science; perceivedtechnology as the same as science; and defined science as an attempt to understand and reveal the unknown. It was found that students in the same age groups made similar statements as in this study. Bell, Blair, Crawford, Lederman (2003) observed that after the educational activity with the 9th and 10th grade students through experiments, the students partially understood the importance of creativity in science.In a study conducted by Çetinkaya (2019), it was found that almost all of the students believed that scientists used imagination and creativity in their research. We obtained gender-related significant differences in the science-technology-research dimension scores of the survey. Female students scored higher than male students. Kılıç, Sungur, Çakıroğlu,andTekkaya (2005)conducted a study with first grade high school students andÇelikdemir (2006)carried out a study involving primary school students and they found that perception of the nature of science varies according to gender.Yenice, Hiğde,andÖzden (2017) determined that there was no gender-related significant difference in secondary school students' views toward the nature of science.On the other hand, we found that the scores obtained from questions about the science-technology-research relationships did not significantly differ with grade level. The mean score of the 7th graders, which had a higher number of students, was higherbut no significant difference was found in the mean ranks. Similarly, in a study by Demir andAkarsu (2013) with sixth and seventh grade students, no significant difference was found in the definition of science and its relation with other disciplines according to grade level.

The second part of the survey includes questions about nature-to-design products. In this part, more than half of the students gave completely true answers to the 7th and 12th questions. This result may be linked withthe fact that children seecocklebur plants anddragonfly wings outside, on TV, or in other media. On the other hand, the majority of the students gave wrong answers to the other questions in this part which were about the images and descriptions of gecko (a lizard), snowshoe hare, shark skin, and termite nest.The reason for this result may be that the students did not have the opportunity to observe these species in their close environment or that the characteristics of these creatures did not attract their attention of them before. Factors such as students' special interests, books they read,

television programs, documentaries they watch, and natural lifestyle can affect their awareness of nature. Naturally, a child living in a rural area and a child living in an urban area and spending time in only playgrounds or indoor environments have different environmental awareness and different interactions with insects, birds, plants, and animals. The ability of students to make design proposals based on examples from nature can be associated with their creativity and innovation skills. The current science curriculum aims not only to provide students with science literacy but also to have 21st-century skills. According to the Partnership for 21 Century Skills (P-21) document(URL-4),learning and innovation skills include "Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration" topics. Students are expected to present alternative ideas in problem-solving and to have product development skills with creative ideas. STEM (science-technology-mathematics-engineering approach) methods and techniques are widely applied to train students as future designers, engineers, and scientists. Biomimicry practices support not only creativity and innovation, but also science process skills, design and manufacturing skills, ecological literacy, and interdisciplinary research skills (Sumrall, Sumrall, & Robinson, 2018; Yıldırım, 2018) It is seen that the majority of educational research on biomimicry is carried out on STEM activities. Sumrall et al. (2018) designed and implemented camouflage-themed activities to teach biomimicry to primary school first grade students. The authors found thatthis practice prompted children to think about the functioning of nature and developed their creative thinking skills. Alperen (2020) made biomimicry educational designs with STEM activities based on the engineering design process within the scope of his master's thesis and stated that during the implementation, the students had more ideas about the living things around their close environment and their properties and that they could identify problems for the engineering design process by examining the properties of living things. Yakişan and Velioğlu (2019) analyzed the designs of 4th graders inspired by the properties of animals and the authors stated that the students were inspired by the creatures they saw in their environment, they produced solutions for the problems they experienced, and this practice contributed to the problem-solving skills of the students. No gender-related significant difference was found in the nature-to-design scores of the students. The school where the implementation was carried out was in a rural area far from the city center. It can be argued that this result might be due to the children living in the same space.The comparison of students' scores according to the grade level showed that significant differences were present between the mean ranks of 5^{th}-7^{th} and 7^{th}-8^{th}grades. The mean scores of 5^{th}, 7^{th}, and 8^{th} grades were calculated as 5.63, 9.90, and 6.06, respectively.These results may be connected with the difference in students' prior knowledge or perceptions of nature.

In the design-to-nature part, the questions with the highest rate of correct answers were sources of inspiration in nature for jet planes, mini robots, and diving fins. On the other hand, the lowest rate of correct answers werespiral staircases, tree pods, and dirt-repellent fabric paints. The mini robots that were inspired by spiders, flies, and ants are technological products used in many fields today. Biomimetic robots, with various biosensors, perceive many effects such as odor, sound, temperature, and impact as stimuli (Bar-Cohen, 2006). Some biological properties of living things such as the flexibility and durability of the spider web, the hardness of the seashells, sharks skin's friction-reducing effect in the water, the sunlight intake and temperature control of the hippopotamus skin, the carbon dioxide capture capacity of the algae, the thermal insulation of the prickly surface of the durian plant are imitated and used in many fields such as industry, textile, architecture, health technology aviation, water sports, and chemistry (Carlson, Ghaey, Moran, Tran& Kaplan, 2006; Karabetça, 2021; Mazzoleni, Maya, Bang, Molina, Barron&PeiLi, 2011). It was an expected result that students gave more correct answers to the questions about things that they see in their close environment. Similarly, since they did not see tree pods before or did not know what a spiral staircase looks like may be explained by the lack of prior knowledge. Although no gender-related significant difference was obtained in the scores received in this part, a significant difference was obtained between the mean scores of 5^{th} and 7^{th} grades. This difference might be associated with the difference in the students' readiness and interest levels. Furthermore, significant differences were found in the total survey scores according to grade level.

The interview conducted with the selected students after the analysis of the survey data revealed that the students made observations about nature and they have noticed situations inspired by nature while designing. Some students did research using books and the internet, whereas this topic

has not attracted the attention of some others. If children spend timein nature, they can develop curiosity and interest in different fields. Curiosity is the key concept for research and inquiry. On the other hand, biomimicry includes defining a problem situation, seeking solutions from nature, and adopting these solutions for the problem (Gardner, 2012). STEM activities are effective in providing students with critical thinking, creativity, communication, problem-solving, and science process skills for science and engineering (Bybee, 2011; Çalışıcı, 2018; Yavuz, 2019).

The results of the present study showed that secondary school students had a moderate level of awareness of biomimicry, they were influenced by their close environment in understanding the link between man-made designs and nature and as the readiness level of the students increased, their linking capacity increased.Some specific activities can be carried out in science classes to support secondaryschool students' understanding and interpretation capacity of science, technology, and nature, and to support them to produce creative solutions by using nature to produce design suggestions. Methods that support the development of 21st-century skills can be used not only for science literacy but also to raise awareness of biomimicry. Moreover, since the current study was carried out in a rural secondary school, similar studies might be carried out inurban areas and with different age groups.

References

Alperen N.F. (2020). Ortaokul 5. sınıf bilim uygulamaları dersine yönelik STEM temelli bir öğretim tasarımı: Doğadan ilham alan teknolojiler. (Unpublishedmasterthesis),Recep Tayyip Erdoğan Üniversitesi, Rize, Turkey.

Avcı, F. (2019). Doğa ve inovasyon: okullarda biyomimikri. *Anadolu Öğretmen Dergisi*, 2(3), 214-233. https://doi.org/10.35346/aod.604872

Bar-Cohen, Y. (2006). *Biomimetics: reality, challenges, andoutlook*. (J. Bar-Cohen, Ed)., Biomimetics: Biologically inspired technologies. Boca Raton, FL: Taylor & Francis Group.

Bell, R.L., Blair, L.M., Crawford, B.A., &Lederman, N.G. (2003). Just do it? Impact of a scienceapprenticeship program on highschoolstudents' understandings of thenature of scienceandscientificinquiry. *Journal of Research in ScienceTeaching*, 40(5), 487-509.https://doi.org/10.1002/tea.10086

Benyus, J. M. (1997). Biomimicry: innovationinspiredbynature. New York: William MorrowandComp, Inc.

Benyus, J. M. (2002). Biomimicry: Innovation inspired by nature.[Elektronik Sürüm]. New York: HarperCollins.

Boga-Akyol, M. and Timur-Ogut, S. (2016). Exploringbiomimicry in thestudents' designprocess. *Design andTechnologyEducation: An International Journal*, 21(1), 21-31.

Büyüköztürk, Ş. (2007), *Sosyal bilimler için veri analizi el kitabı*, Ankara: Pegem A Yayıncılık

Bybee, R. W. (2011). Scientificandengineeringpractices in K–12 classrooms: Understanding a frameworkfor K–12 scienceeducation. *TheScienceTeacher, 78* (9), 34–40

Carlson, J., Ghaey, S., Moran, S., Tran, C.A. and Kaplan, D.L. (2006). Biologicalmaterials in engineeringmechanisms, (in J. Bar-Cohen, Ed)., Biomimetics: Biologically inspired technologies. Boca Raton, FL: Taylor & Francis Group.

Creswell, J. W. (2009). *Researchdesign: Qualitative, quantitative, andmixedmethodsapproaches* (3rd ed.). London: Sage Publications, Inc.

Creswell, J.W. (2013) *Researchdesign: Qualitative, quantitative, andmixedmethodsapproaches*. 4th Edition, London: SAGE Publications, Inc.

Çalışıcı, S. (2018). *FeTeMM uygulamalarının 8. sınıf öğrencilerinin çevresel tutumlarına, bilimsel yaratıcılıklarına, problem çözme becerilerine ve fen başarılarına etkisi*. (Unpublishedmasterthesis),Gazi University, Ankara, Turkey.

Çelikdemir, M. (2006). *İlköğretim öğrencilerinin bilimin doğasını anlama düzeylerinin araştırılması,*(Unpublishedmasterthesis),Middle East TechniqueUniversity, Ankara, Turkey.

Çetinkaya, E. (2019). Açık-düşündürücü yaklaşıma dayalı etkinliklerin ortaokul öğrencilerinin bilimin doğası görüşlerine etkisi. *Journal of TheoreticalEducationalScience*, 12(1), 227-259.https://doi.org/10.30831/akukeg.382049

Ersanlı, C. C. (2016). Fizik eğitiminde biyomimikri verileri kullanımın yeri ve önemi. *5 th International Vocational Schools Symposium*, Prizren, Kosova, 18 - 20 May 2016.

Gardner, G. E. (2012). Using biomimicrytoengagestudents in a design-basedlearningactivity. *TheAmericanBiologyTeacher*, 74(3), 182-184.https://doi.org/10.1525/abt.2012.74.3.10

Ginsberg, M., Schiano, J., Kramer, M., Alleyne, M., (2013). A casestudy in bio-ınspiredengineeringdesign: defenseapplications of exoskeletalsensors, *Defense& Security Analysis*, 29(2), 156-169.https://doi.org/10.1080/14751798.2013.787798

Hastürk, H.G., Öztürk, N., Demir, R. & Kartal, T. (2014). Opinions of studentshavingeducation in variouslevelsaboutthenature of science, *Journal of History School (JOHS*), 7(13), 671-688. http://dx.doi.org/10.14225/Joh479

Inner, S. (2019). Biyomimikri ve parametrik tasarım ilişkisinin mimari alanında kullanımı ve gelişimi. *Tasarım Enformatiği Dergisi*, 1(1), 15-29.

Karabetça, A. (2018). Biyomimikri destekli tasarım ölçütleri ile yenilikçi mekanlar yaratılması. *TheTurkish Online Journal of Design Art andCommunication*, 8(1), 104-111. DOI: 10.7456/10801100/010

Karabetça, A.R. (2021). Ormanlar gibi sürdürülebilir ve dirençli şehirler tasarlanabilir mi? *TheTurkish Online Journal of Design, Art andCommunication* – TOJDAC, 11 (2), 334-346.

Kılıç, K., Sungur, S., Çakıroğlu, J. &Tekkaya, C. (2005). Ninth gradestudents'understanding of thenature of scientificknowledge, *Hacettepe UniversityJournal of EducationFaculty*, 28 ,127-133.

Kim, S. (2019). Development andeffect of biomimicry robot education program based on technologyeducation. *Journal of Convergencefor Information Technology*, 9(4), 109-117. https://doi.org/10.22156/CS4SMB.2019.9.4.109

Mahgoub, Y. M. &Alawad, A. A. (2014). Theimpact of teachingbiomimicrytoenhancethinkingskillsforstudents of art education in highereducation. *PenseeJournal*, 76(4), 2-11.

Mazzoleni, I., Maya, A., Bang, A., Molina, R., Barron, F.&PeiLi, Y., (2011), Biomimeticenvelopes: Investigatingnaturetodesignbuildings, Proceedings of the First AnnualBiomimicry in HigherEducationWebinar, *TheBiomimicryInstituteWebinarDocument*, 27- 32.

Miles, M. B., &Huberman, A. M. (1994). *Qualitativedataanalysis: An expandedsourcebook (2nd ed.).*Sage Publications, Inc.

Panchuk, N., (2006).*An explorationintobiomimicryanditsapplication in digital&parametric [architectural] design*. Master of Architecture Thesis, University of Waterloo.

Peters, T., (2011). Nature as measure: Thebiomimicryguild. *Architectural Design*, 81(6), 44-47. https://doi.org/10.1002/ad.1318

Sanne, F., Risheim, I. andImpelluso, T. (2019). Inspiringengineering in the K -12: biomimicry as a bridgebetweenmathandbiology. *Proceedings of the ASME 2019 International MechanicalEngineering& Exposition*. Bergen, Norway, 8 - 14 November 2019

Subsoontorn, P., Ounjai, P., Ngarmkajornwiwat, P., Sakulkueakulsuk, B., Pensupha, N., Surareungchai, W. &d Pataranutaporn, P. (2018). Hackbiodesign: An integrative STEAM educationplatform forbiology, engineering, anddesign. *In 2018 IEEE International Conference on Teaching, Assessment, and Learning forEngineering (TALE)*, Wollongong, Australia, 4 - 7

December 2018, 1016-1021.

Sumrall, W. J., Sumrall, K. M. andRobinson, H. A. (2018). Using biomimicrytomeet NGSS in thelowergrades. *ScienceActivities*, 55(3-4), 115-126.

URL 1 (2020). https://peyzax.com/tasarimda-dogadan-ilham-alma-biyomimikri-ornekleri/

retrived on 25. 09.2020

URL-2(2019).https://www.teachengineering.org/activities/view/cub_bio_lesson05_activity1retrived on 05.11.2019

URL-3 (2019). http://www.greeneducationfoundation.org/institute/lessonclearinghouse/457-biomimicry_the_nature_of_genius.html retrived on 05.11.2019

URL-4 (2022). http://www.battelleforkids.org/networks/p21

Volstad, N.L., Boks, C., 2012. On theuse of biomimicry as a usefultoolfortheındustrialdesigner. *Sustainable Development*, 20, 189-199.https://doi.org/10.1002/sd.1535

Yakışan, M. ve Velioğlu, D. (2019). İlkokul 4.sınıf öğrencilerinin biyomimikri algılarına yönelik yaptıkları çizimlerin analizi. *Gazi UniversityJournal of EducationFaculty*, 39(2), 727-753.https://doi.org/10.17152/gefad.547807

Yavuz, Ü. (2019). *İlkokul fen bilimleri dersinin fen, teknoloji, mühendislik ve matematik (FeTeMM) etkinlikleri ile işlenmesi,* ((Unpublishedmasterthesis). Afyon Kocatepe University, Afyonkarahisar, Turkey.

Yıldırım, B. (2019). Fen bilgisi öğretmen adaylarının STEM eğitiminde biyomimikri uygulamalarına yönelik görüşleri. *Gazi UniversityJournal of EducationFaculty*, 39(1), 63-90.

Yıldırım, B. andAltun, Y. (2015). InvestigatingtheEffect of STEM EducationandEngineering Applications on ScienceLaboratoryLectures. *El-CezeriJournal of ScienceandEngineering*, *2*(2), 28-40.

Yıldız, H. (2012*). Endüstri ürünleri tasarımı kapsamında biyomimetik tasarımın yeri ve metodolojisi.*(Unpublishedmasterthesis), İstanbul TechnicalUniversity,Istanbul, Turkey.