'an ordinary evening in Bukhara' Bukhara, Uzbekistan (Fahri Tarhan, 2019)

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Evaluation of the 2017 updated secondary school English curriculum of Turkey by means of theory-practice link

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ABSTRACT This study evaluates the 2017 updated secondary school English curriculum of Turkey with the frame of Stake's (1967) congruence-contingency model. The study employed a mixed-methods research design. In this regard, triangulation was employed to provide data diversity. Four different data gathering tools were used: document analysis, interviews, structured questionnaires and in-class observations. The questionnaire data were gathered from 96 English language teachers, working in various cities of Turkey, and the interviews were conducted with seven English language teachers working at a public school in Ankara. In addition, classroom observations were conducted at four different classes in the same school. The findings of the study indicated that teachers considered the updated curriculum suitable and effective. However, in-class observations displayed that there are important gaps in bridging theory and practice. Thus, if there is a huge gap between what was intended and what was carried out, then first, an English as a foreign language education policy document should be prepared, and a unique foreign language-teaching ecosystem to include all stakeholders should be targeted.

Keywords: *Curriculum evaluation, English language teaching, Foreign language policy, Teacher training*

Türkiye'de 2017'de güncellenen ortaokul İngilizce öğretim programının kuram-uygulama bağı kapsamında değerlendirilmesi

ÖZ Bu araştırmada 2017 yılında güncellenen ortaokul İngilizce öğretim programlarının Stake'in (1967) uygunluk-olasılık modeli bağlamında değerlendirilmesi amaçlanmıştır. Araştırmada karma araştırma deseni benimsenmiştir ve bu bağlamda veri çeşitliliği sağlamak için üçgenleme tekniği kullanılmıştır. Araştırmada doküman analizi, görüşme, yapılandırılmış anket ve sınıf içi gözlemler şeklinde dört farklı veri toplama aracı kullanılmıştır. Anket verileri Türkiye'nin farklı illerinde çalışan 96 İngilizce öğretmeninden toplanmış, görüşmeler Ankara ilinde bir devlet ortaokulunda çalışmakta olan 7 İngilizce öğretmeni ile yapılmıştır. Diğer yandan, sınıf içi gözlemler aynı okulda dört farklı sınıf düzeyinde gerçekleştirilmiştir. Araştırma sonuçları öğretmenlerin güncellenen İngilizce öğretim programlarını uygun ve etkili bulduklarını göstermiştir. Ancak sınıf içi gözlemler, kuram-uygulama bağını sağlamada önemli problemler olduğunu göstermiştir. Bu nedenle hedeflenen ile uygulanan arasında önemli bir fark mevcut ise öncelikle yabancı dil olarak İngilizce dil eğitimi politika belgesi hazırlanması ve bu doğrultuda tüm paydaşları kapsayacak şekilde özgün bir yabancı dil öğretim ekosistemi amaçlanması gerekmektedir.

Anahtar Sözcükler: *Program değerlendirme, İngilizce öğretimi, Yabancı dil politikası, Öğretmen yetiştirme*

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INTRODUCTION

In the globalized 21st century, knowing a foreign language is the norm. Nowadays, education systems are expected to offer a second or even a third language. Individuals are increasingly expected to learn and use foreign languages in communicative environments. Similar to many other countries, primary and secondary school education in Turkey is focused on teaching and learning English as a foreign language (EFL) along with bettering language instruction.

Until 1997, the earliest that English was taught in Turkey was at secondary school. In 1997, with the introduction of the eight-year compulsory education, English was offered from the fourth grade. As a result of the changes in other countries, there emerged an interest in starting foreign language education at an earlier age. Compulsory education was extended from 8 to 12 years, as a result of the Law on Primary Education (Official Gazette, 2012). In this context, the 4 + 4 + 4 system was introduced, and it was decided that foreign languages teaching should start in the second grade with two hours of instruction. Hence, a new foreign language curriculum was prepared and applied in the academic year of 2013–2014 by the Ministry of National Education (MoNE). In the curriculum, it was stated that the majority of students in Turkey were unable to use English as a language of communication and that was related to the status of the language as an academic requirement, rather than a communication tool. The curriculum was proposed to establish a relationship between the material used and the students' daily lives (MoNE, 2013).

The curriculum covers the objectives expected to be achieved by the students for each course, the gains representing the knowledge, skills and attitudes that are intended to be acquired by the students, in line with these objectives, and the explanation of the teaching and evaluation methods, techniques and strategies to be used in the process of transferring these to the students. The curriculum also covers the learning objectives that indicate the level of knowledge and skills that the students must achieve at each grade level. In this way, it guides the teachers and parents informing about what language knowledge and skills children are expected to acquire (MoNE, 2018). As Daloğlu (1996) stated, the most important issue to teach EFL is to establish a good curriculum with well-identified objectives. In particular, in the context of academic English, its success is only possible with a well-grounded curriculum.

2017 Curriculum Reform and English Language Teaching Curriculum Update

All courses in the EFL curriculum for primary and secondary schools in Turkey were updated in 2017, and they were put into practice throughout the country in 2018. The MoNE based the curriculum update on considerations encompassing the following aspects: (MoNE, 2018): Research on skills that students must have in order to continue their education; Comparison and evaluation studies about curricula of countries with the best educational practices; National examinations; International examinations.

As a basis for the comprehensive curriculum development study, low scores from national-international examinations and the reasons behind meeting the expectations of higher education systems, together with the expectations of the market, have been put forward. It was further stated that international comparisons are used to analyze different education systems and to determine the ways of developing the Turkish education system based on these findings. For instance, one of the ways of analyzing educational systems was the comparison of the educational practices and curricula of different countries, based on the results of international evaluations. When the updated English curriculum was examined, an emphasis was given on the four fundamental language skills of listening, speaking, reading and writing (MoNE, 2018), as shown in Table 1.

Table 1.
Fundamental points of the proposed curriculum

Levels (CEFR)	Hours/ week	Grades	Skill focus	Main activities/strategies
1 (A1)	2 hours	2	listening & speaking	TPR (Total physical response) / Arts and Crafts/ Drama
		3	listening & speaking very limited reading & writing	
		4	listening & speaking very limited reading & writing	
2 (A1)	3 hours	5	listening & speaking limited reading very limited writing	Drama / Role play
		6	listening & speaking limited reading limited writing	
3 (A2)	4 hours	7	primary: listening & speaking secondary: reading & writing	Theme-based
		8	primary: listening & speaking secondary: reading & writing	

As can be seen in Table 1, the curriculum focuses on all four skills, and emphasis is given to listening and speaking in the second, third, and fourth grades. It can also be seen that in grades five to six, listening and speaking are emphasized and reading and writing are introduced at a limited level. Teaching methods, such as drama and role play, are emphasized. For grades seven to eight, the use of all four skills is encouraged with an emphasis on theme-based instruction. It is evident from the updated curriculum that it fosters the use of communicative language teaching (CLT) with a focus on values education.

Another salient feature of the curriculum is that the principles and descriptors of the Common European Framework of Reference for Languages: Learning, Teaching, Assessment (CEFR) are closely followed. The new curricular model emphasizes language use in an authentic communicative environment. As no single language teaching methodology is seen as flexible enough to meet the needs of learners at various stages and to address a wide range of learning styles, an eclectic mix of instructional techniques has been adopted, drawing on an action oriented approach in order to allow learners to experience English as a means of communication, rather than focusing on the language as a topic of study (MoNE, 2018, p.3). In addition, in order to impress on students, the role of English as a means of relaying needs and wants, voicing opinions and beliefs, building relationships, and so on, the new curricular model focuses on language learning as communication. In other words, learners/users engage in activities which require actual communication between peers or between students and their teacher, such as creating a game as a group and then playing it with classmates, rather than rehearsing prepared material (p.4).

Curriculum Evaluation

Systematic and continuous evaluation of any curriculum and identification of the strengths and weaknesses is extremely important for the effective teaching of English. In addition, systematic curriculum evaluation will provide a better implementation of curricula and provide guidance to teachers and students. In this regard, the evaluation process may be defined as the process of collecting, editing and fine-tuning the data (Ornstein & Hunkins, 2016). According to Varış (1997), curriculum evaluation has an important and permanent place in its development. Since the process requires teamwork, group working techniques and coordination are included. Assumptions are made for the training of qualified students and in-class (inside and outside school) activities are compared; specific method trials are attempted, and the richness of the methods is highlighted. Processes and results are evaluated continuously and shaped according to the feedback; new assumptions are tried out to develop one or more of the structural elements. Thereby, the continuity of curriculum development is ensured. A continuous assessment process is required to observe the implementation of the new curricula. As

Gözütok (2001) and Ültanır (2003) suggested, questioning and evaluating the implementation of the prior curricula is the starting point for curriculum development.

The extent to which the competences targeted by an updated curriculum on paper are reflected in realized implementation is extremely important, in terms of strengthening the theory-practice link and shedding light on the work to develop the curriculum. Many studies show that curriculum updates carried out under the name of reform are not reflected in the implementation and remain limited to being on paper (Cheserek & Mugalavi, 2012; Wang, 2006). EFL curriculums of countries where English is taught as a foreign language show that curriculum change is seldom transferred to real class implementations (Hamid & Honan, 2012; Yaacob, 2006). However, as Varış (1997) stated, in curriculum development, evaluation should keep an important and permanent place. Processes and results should be evaluated continuously, and new assumptions should develop one or more of the structural elements, according to the feedback received. Thus, this will ensure the continuity of the curriculum development mechanism.

Studies on the evaluation of previous English teaching curricula, in Turkey, usually focused on teachers' opinions and perceptions (Büyükduman, 2005; Demirlier, 2010; Er, 2006; Erbakan, 2001; Erbilen Sak, 2008; Erdoğan, 2005; Kandemir, 2016; Dinçer & Saracaloğlu, 2018). However, studies that focused on the alignment between policy and practice in the Turkish context were extremely limited (such as Dinçer, 2013). In one salient study, Yücel, Dimici, Yıldız and Bümen (2017) analyzed the implementation of English language curricula published over the last 15 years. They found out that the communicative approach was adopted in secondary school curricula but could not be practiced as suggested by other studies and that in the 2011 secondary school program the interests and needs of the students were ignored in content and objective design. In addition, as the updated English curriculum was first implemented in 2018, very few studies in the literature were observed to be evaluating the updated version. A study by Yüce (2018) tried to find out the compatibility of the secondary education ninth grade updated English language teaching program, to the principles of the CEFR. The results showed that the outcomes of the 9th grade English language teaching program were not completely compatible with the proficiency descriptors of the CEFR, and issues such as course materials, course hours, self-assessment and in-service training activities for the teachers, affected the implementation of the program negatively. However, the activities of the EFL program were appropriate for and suited to the students' language levels and ages. In another study, Erdem and Yücel Toy (2017) wanted to determine the needs for the foreign language oriented 5th grade English curriculum. According to the findings of their study, the problems most frequently encountered by English teachers of the foreign language oriented 5th grades were the size of the classes, the lack of a prepared curriculum for 2016-2017 academic year and the lack of a course book. Finally, Ağçam and Babanoğlu (2018) compared the primary school and secondary school English curricula of 2017 through an analysis of the intended learning outcomes and found out that primary school English course objectives were extensively designed to address students' lower- rather than higher-order cognitive skills. The current study, expanding the findings in the previous research, was designed to find out if there is such a gap between theory and practice; in other words, to evaluate the updated secondary school English curriculum of Turkey, based on Stake's evaluation model of congruence-contingency.

Stake's Congruence-Contingency Model

According to Stake (1967), in order to evaluate, an educator needs to gather certain data, and these data are likely to be from several different sources. The purpose might be description or judgment, but in each case, three bodies of information should be tapped into. In the evaluation report, it can be helpful to distinguish between antecedents, transactions and outcomes data.

According to Stake (1967), there are two principal ways of processing descriptive evaluation data: finding the contingencies among antecedents, transactions, and outcomes and finding the congruence between "*intents*" and "*observations*". The data for a curriculum are congruent if what was intended actually happens. The model is shown in Figure 1.

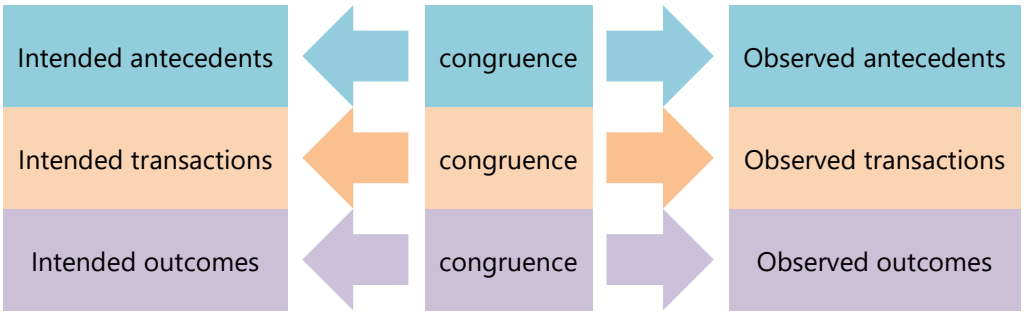

Figure 1. Stake's congruence-contingency model

Stake's model is useful for demonstrating the realization level of the features and targets expected in a curriculum. Therefore, Stake's congruence-contingency model was adopted within the scope of the present research. It considers all three levels of congruence and contingency as intended and observed antecedents, transactions and outcomes. Antecedents is about the readiness and introductory statuses of the students and the learning environment. Thus, antecedents are not the focus of this study. Similarly, since outcomes refer to the degree of student learning or success, they were also not targeted in this research. Instead, this study targeted on congruence and contingency among the intended and observed transactions. In this context, the 2017 updated secondary school English language curriculum in Turkey, put into practice in 2018, was examined through the secondary school English teachers' opinions and classroom observations. The reason for considering the secondary school level in the research was that different expectations for grades five to six and seven to eight can be observed in the curriculum structure. While drama/role-play techniques were proposed for grades five to six, a theme-based structure was proposed for grades seven to eight. On the other hand, for the former, limited reading and very limited writing was suggested; however, for the latter grades, teaching all the skills with a theme-based approach was suggested. For these reasons, the evaluation of the secondary school English curriculum was considered to be salient.

Research Objectives

The primary aim of this study was to evaluate the updated secondary school English language curriculum, in terms of intended and observed transactions, to examine the alignment between policy and practice.

The research questions of the study are:

How do teachers perceive the updated curriculum regarding its objectives, content, generation of learning experiences and assessment?

How is the updated English curriculum implemented in classrooms?

METHODOLOGY

The present study employs a mixed-methods research design. This study is an instrumental case study aiming at providing information on EFL teaching in the context of secondary education in Turkey and, consequently, making suggestions to address identified problems by examining the case of a secondary school in Ankara. The researcher is interested in studying the particular case, only as a means to some larger goal (Fraenkel, Wallen & Hyun, 2012). As data gathering tools, documents, interview form, questionnaire and in-class observation form were utilized. The different data collection tools allowed triangulation in order to enhance the reliability of results. The data from multiple sources were analyzed

together. The reason behind the triangulation was that the strengths of the various data gathering tools would complement each other and offset each method's respective weaknesses. (Fraenkel, Wallen & Hyun, 2012).

Participants and Sampling

For the online questionnaire, the snowballing sampling method was considered, through which all voluntary participants in various provinces of Turkey were targeted. For the interviews and observations, one public secondary school in Ankara employing intensive English language teaching was chosen. This was believed to be a suitable school with mostly experienced English language teachers (minimum 15 years of experience) and students from various socio-economic backgrounds. The selected school is an urban school, and it employs an English intensive education at the fifth-grade level. Demographic information on the teachers responding to the online questionnaire is given in Table 2.

Table 2.
Participants in the online questionnaire

Variable	Category	f	%
Gender	Male	21	22
	Female	75	78
Age	0-25	15	16
	26-40	63	66
	41-50	14	15
	51 and above	4	3
Type of school	Public	92	96
	Private	4	4
Undergraduate department	English language teaching	79	82
	Others	17	18
Graduate degree	Yes	2	2
	No	94	98
Experience	0-5	42	44
	6-10	27	28
	11-15	9	9
	16 and more	18	19
Knowledge about the new curriculum document	Yes	73	76
	Partly	23	24

An overview displaying demographic data of the participants in the interviews is shown in Table 3.

Table 3.
Participants in the interviews

Variable	Category	f	%
Gender	Male	1	14
	Female	6	86
Age	0-25	1	14
	26-40	4	57
	41-50	2	29
	51 and above		
Undergraduate curriculum type	English language teaching	4	57
	Others	3	43
Graduate degree	Yes	7	100
	No	-	-
Experience	0-5		
	6-10	-	-
	11-15	-	-
	16 and more	7	100
Attendance to in-service training	Yes	1	14
	No	6	86

Participants for the interviews comprised seven English language teachers working at a public elementary school all with a minimum 15 years of teaching experience. None of them had a graduate

degree and the majority had not attended any kind of in-service training. As shown in Table 3, most of the interviewees were aged between 41 and 50 and they were all above 26 years of age.

Data Collection Tools

As data collection tools, a semi-structured interview form, classroom observation forms and a structured online questionnaire were employed; additionally, documents were analyzed. Data collected from the documents, interviews, and questionnaires were used to make inferences about the theory-practice link, by establishing connections with data gathered from the in-class observations.

Document Analysis

For this study, the 2017-updated curriculum document of MoNE acted as the main document as well as the course books and supplementary materials/resources delivered by MoNE. Sample lesson plans of the observed teachers and the electronic tools they used also acted as documents. The document analyses provided the grounds for the online questionnaire, semi structured interview form, and in-class observation form: The documents provided by MoNE entailed the components that needed to be considered in the actual instructional practice as evidence if the curricular changes had been implemented sufficiently.

Structured Online Questionnaire

A structured questionnaire consisting of two sections was designed, informed by the updated English curriculum. The first section collected demographic data while the second section elicited the teachers' opinions about various dimensions of the updated curriculum. The questions within each section of the questionnaire were formed based on the main components and expectations stated in the curriculum. All questions were first, categorically defined as "yes", "no", and "partly", and the participants were then asked to write about their opinions. Thus, detailed responses of the participants were targeted. The draft questionnaires were then sent to three academics in the field of English language teaching, to check for the suitability of the questions. The questions were fine-tuned, based on the suggestions of the experts, and the questionnaire was then piloted with five English language teachers working in Ankara. The suggested fine tunings were employed, based on the opinions of these teachers, and the questionnaire was finalized. There are nine items in the first section, ten items about the objectives of the curriculum, 13 items about the content, eight items about the learning experiences, eight items about evaluation, and 22 items about the implementation process.

Semi-structured Interviews

Interviews with seven English language teachers were conducted in a public secondary school in Ankara. Although the school is an urban school, in the heart of Ankara, various students from the nearby rural districts attend this school. The reason behind the selection of this school was that all the English language teachers were experienced in teaching English to secondary school level students, and that the school utilized an English-language intensive education for especially, the fifth-grade level. A semi-structured interview form consisting of 11 questions was composed, based on the information gathered through document analyses. Interview questions were first sent to three experts in the field of English language teaching to examine for suitability, and the necessary fine tuning was made based on the feedback gathered from these experts. Subsequently, the interview questions were piloted with two English language teachers working at a secondary school in Ankara. As a result, the questions were finalized. Interviews were conducted with seven English language teachers at the selected secondary school in May 2019. All interviews were tape-recorded with the permission of the participants and then transcribed. Each interview lasted around 30 minutes. Interviews were conducted in Turkish, as it is the native language of all the participants.

Classroom Observations

Classroom observations were carried out to reveal the alignment between policy and practice (Carless, 2004). An observation form consisting of 20 items was developed based on the key indicators of the updated secondary school English curriculum. The form was sent to three English language teaching academics to check for the suitability of the statements. The items were categorically defined as "yes", "no", and "partly", and an open-ended section was added next to each item for further comments and details. Thus, the form served both as a checklist defining key dimensions, as suggested in the curriculum, as well as a detailed form to gather comments on each item. One-hour classroom observations were carried out at each classroom level (grades five to six and seven to eight). The aim of the observation form was to figure out if there was a gap between theory-practice link in terms of the intended and observed curriculum implementation. Thus, the form consisted of items that the updated curriculum required such as the implicit use of grammar in classes and the researcher checked whether each requirement was fulfilled in different classes. The same observation form was used at all grades. The observer identified himself as a researcher but stuck to non-participant observation as he did not interfere in classroom practice.

Data Collection Procedures

Data were collected over a two-month period. First, documents were collected and analyzed to examine the updated curriculum and to develop the data collection tools, then the online questionnaire was sent to English language teachers working in various cities of Turkey. Interviews with teachers were conducted in May 2019. Classroom observations were then carried out to determine the alignment between intended and observed transactions of the curriculum. The observations were carried out in four different EFL classrooms. Each class was observed once, and each observation lasted for one hour; a total of four lessons were observed.

Data Analysis

Data regarding the online questionnaire were analyzed by means of descriptive statistics. Data from the interviews were analyzed using content analysis. Teachers' answers to the interview questions were first transcribed and sent back to the participants for clarification. Then they were analyzed using the NVivo software. As for the coding process, a pattern-coding method was used (Miles & Huberman, 1994). Consent was obtained from the TED University Ethical Committee for the suitability of the study in terms of ethical codes and guidelines, No: 27535802-020/, Date: 09.05.2019. Further consent was gathered from the Provincial Directorate of National Education-Ankara, No: 14588481-605.99-E.7723497, Date: 16.04.2019. Data regarding classroom observations were analyzed through frequency analyses.

FINDINGS

In the following sections, the findings are reported for the structured online questionnaire, the semi-structured interviews, and the classroom observations separately. For the questionnaire, the teachers' views on the dimensions examined (curriculum objectives, content, teaching-learning process, assessment and implementation process) serve as guiding principles to present the findings. The results for the interviews are reported in terms of perceived strengths and weaknesses. The results concerning classroom observations focus on to what extent curricular requirements were considered in actual instructional practice.

Findings Regarding the Structured Online Questionnaire

The analysis of the questionnaire was carried out with data gathered from 96 English language teachers, and descriptive statistics (percentages) were used to analyze the quantitative data.

Opinions of English language teachers on the suitability of objectives

The opinions of English language teachers on the suitability of the objectives of the updated secondary school curriculum are presented in Table 4. The most striking and the highest gained value is that most of the teachers agreed that the program aims to use English for communication purposes, rather than focusing on language structures only. On the other hand, approximately half of them agreed that, with the lowest gained value, the objectives of the program could be reached by the students under the current circumstances. On the whole, the majority of the teachers regarded the objectives of the updated curriculum as suitable and effective.

Table 4.
Opinions of English language teachers regarding the suitability of objectives

Variables	Yes	%	Partly	%	No	%
The program aims to use English in an authentic and communicative environment.	65	68	28	29	3	3
The program aims to use English for communication purposes rather than language structures.	79	82	13	14	4	4
Objectives highlight the use of values such as friendship and justice.	63	66	26	27	7	7
Objectives highlight the use of key competences such as communication, and digital skills.	67	70	24	25	5	5
Objectives highlight the use of learner autonomy.	59	62	26	27	11	12
Objectives highlight the use of valuing other cultures.	72	75	19	20	5	5
Objectives were written correctly and effectively by taking into account main principles such as 1 main verb in each objective.	70	73	23	24	3	3
Objectives targeted to improve affective skills of students as well as cognitive skills.	78	81	15	16	3	3
The program aimed to make English learning process interesting and fun through its objectives to meet the diverse needs of students at various levels.	68	71	21	22	7	7
I believe that objectives of the program can be reached by students under current circumstances.	54	56	30	31	12	13

Opinions of English language teachers on the suitability of content

Opinions of the English language teachers on the suitability of content of the updated secondary school curriculum are presented in Table 5.

Table 5.
Opinions of English language teachers regarding the suitability of content

Variable	Yes	%	Partly	%	No	%
The program covers authentic materials to stress the communicative perspective.	59	62	30	31	7	7
The program provides materials as learning tasks for task-based learning.	67	70	24	25	5	5
The program provides materials and learning sources derived from authentic sources.	53	55	26	27	17	17
The program provides suitable, interesting and achievable learning contexts for both teachers and book writers.	53	55	29	30	14	15
The program leads teachers to prepare materials covering values.	57	59	26	27	13	14
Values such as friendship and justice are interwoven in each unit and theme of the curriculum.	59	62	27	28	10	10
The program provides samples of activities to cover values and ethical principles.	66	69	22	23	8	8
Structures and linguistic functions are implicitly provided for the authentic use of the language.	78	81	16	17	2	2
The content stresses the development and appreciation for students' unique cultures.	71	74	20	21	5	5
The content stresses the value of home culture in order to avoid the formation of negative attitudes.	70	73	22	23	4	4
The contents of 7 and 8th grades were organized as themes.	78	81	13	14	5	5
The content exemplifies characters and places that learners are likely to encounter.	71	74	20	21	5	5
I believe that contents of the program are suitable for students under current circumstances.	46	48	31	32	19	20

The most striking and the highest gained values are that most of the teachers agreed that structures and linguistic functions are implicitly provided for the authentic use of the language in an interactive context, rather than as a separate entity, and the content for the seventh and eighth grades were organized as themes. On the other hand, less than half of the teachers agreed that, with the lowest gained value, contents of the program are suitable for students under the current circumstances. It could be observed that the majority of teachers regarded the contents of the updated curriculum as suitable and effective.

Opinions of English language teachers on the suitability of teaching-learning process

The opinions of the English language teachers on the suitability of teaching-learning process of the updated secondary school curriculum are presented in Table 6.

Table 6.
Opinions of English language teachers regarding the suitability of the teaching-learning process

Variable	Yes	%	Partly	%	No	%
The program stresses English as the medium of instruction in class to improve communicative competence.	79	82	13	14	4	4
The program provides activities such as game play.	67	70	24	25	5	5
The program offers various teaching methods and techniques to stress the values.	62	65	24	25	10	10
The program takes and exemplifies teaching-learning and assessment processes as a whole to diversify teaching techniques of teachers as well as learning strategies of students.	71	74	22	23	3	3
The program stresses techniques such as drama and role-play in 5th and 6th grades.	64	67	28	29	4	4
Activities for 5th and 6th grades rely on listening and speaking skills.	64	67	30	31	2	2
Reading and writing skills are adequately addressed in 7th and 8th grades.	68	71	26	27	2	2
I believe that teaching-learning process of the program is suitable for students under current circumstances.	64	67	23	24	9	9

A large majority of the teachers agreed that the program stresses on English as the medium of instruction in class to improve communicative competence. Showing the lowest level of agreement in the dimension teaching-learning process, more than half of the teachers agreed that the program offers various teaching methods and techniques to stress on values. As all the variables are over 50 %, it can be said that majority of the teachers regarded the teaching-learning process of the updated curriculum as suitable and effective.

Opinions of English language teachers on the suitability of assessment

The opinions of the English language teachers on the suitability of the assessment process of the updated secondary school curriculum are presented in Table 7.

Table 7.
Opinions of English language teachers regarding the suitability of assessment process

Variable	Yes	%	Partly	%	No	%
Assessment procedures of each unit exemplify samples as to what is expected from the teachers.	69	72	20	21	7	7
Assessment samples create positive washback.	69	72	20	21	7	7
Assessment is mainly based on alternative and process-oriented techniques.	67	70	21	22	8	8
The program provides samples of self-assessment.	76	79	15	16	5	5
The program provides samples of checklists for self-assessment.	79	82	13	14	4	4
Both process and product-oriented assessment techniques are used to measure students' communicative competence.	67	70	23	24	6	6
Various assessment techniques are exemplified to support students with their own pace of learning in and out of class.	49	51	35	37	12	13
I believe that assessment process of the program is suitable for students under current circumstances.	57	59	31	32	8	8

The most striking and the highest gained value is that most of teachers agreed that the program provides samples of checklists for self-assessment. On the other hand, half of them, with the lowest gained value, agreed that various assessment techniques are exemplified to support students with their own pace of

learning, in and out of class. As all the variables are over 50 %, it can be said that the majority of teachers regarded the assessment process of the updated curriculum as suitable and effective.

Opinions of English language teachers regarding the implementation process

The opinions of the English language teachers regarding the implementation process of the updated secondary school curriculum are presented in Table 8.

Table 8.
Opinions of English language teachers regarding the implementation process

Variable	Yes	%	Partly	%	No	%
The materials that I use in class cover the key competences stressed in the curriculum.	64	67	30	31	2	2
I can align values with the activities that I use in class.	73	76	19	20	4	4
I can focus on strengthening the communication in class rather than trying to rush over to cover the topics of the curriculum.	48	50	30	31	18	19
Students in my classes can listen and speak as if they were in an authentic environment.	46	48	37	39	13	14
The communication in my classes is in English as much as possible.	51	53	39	41	6	6.3
The communication process in my classes is for creation of meaning.	84	88	10	10	2	2
I use the structural and linguistic elements of the language implicitly to create meaning rather than focusing on them as separate topics.	69	72	22	23	5	5
I can adequately focus on cultural elements in my classes.	68	71	25	26	3	3
I can adequately focus on values in my classes.	73	76	20	21	3	3
I can lead students to use various learning strategies.	83	87	12	13	1	1
My students can transfer their knowledge and skills of English into every phase of learning process.	54	56	36	38	6	6
I provide materials to my students so that they can reinforce what they already know.	83	87	12	13	1	1
My students can create materials to share with other classes and students.	64	67	26	27	6	6
My students can learn English by creating with language rather than learning about the language.	57	59	33	34	6	6
I can get adequate in-service training during the implementation of the updated curriculum.	37	39	25	26	34	35
I focus on listening and speaking skills with 5th and 6th graders rather than reading and writing.	47	49	29	30	20	21
I adequately focus on reading and writing skills with 7th and 8th graders.	79	82	13	14	4	4
I believe that such techniques as drama and role-play are effective for 5th and 6th graders.	83	87	11	12	2	2
I can align different courses in the frame of the Thematic approach with 7th and 8th graders.	74	77	21	22	1	1
I use alternative assessment techniques such as self and peer assessment rather than product-oriented techniques such as written test or quiz.	48	50	25	26	23	24
I develop and use materials derived from authentic sources to improve the communication process.	75	78	18	19	3	3
I can adequately implement the updated curriculum in my classes under current circumstances.	63	66	32	33	1	1

The most striking and the highest gained values are that most of the teachers stated that the communication process in their classes was to create meaning, and that they could direct students to various learning strategies. On the other hand, few of them agreed that they could get adequate in-service training during the implementation of the updated curriculum; students in their classes could listen and speak as if they were in an authentic environment; they focused on listening and speaking skills with the fifth and sixth graders rather than reading and writing. As there are only three variables below 50 %, it can be said that the majority of the teachers regarded the implementation process of the updated curriculum as suitable and effective.

Interviews with English Language Teachers

The answers of the seven English language teachers interviewed were analyzed using content analysis and presented under "*positive opinions*" and "*opinions regarding the suggested improvements*"

Positive opinions regarding the updated curriculum and its implementation

Figure 2 visualizes the positive responses of the teachers interviewed. The values provided in the parentheses represent the frequencies of opinions. Similarly, the thickness of the arrows represents the relative density of opinions. The best part of the curriculum, according to the teachers, is that it focusses heavily on the communicative approach, is based on thematic instruction, fosters technological support and EBA (education information technologies network) platforms, and that it is suitable for foreign language intensive secondary schools.

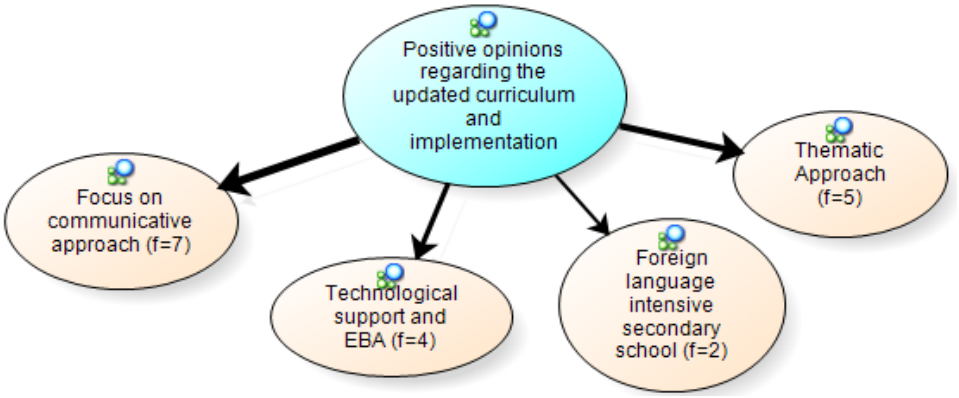

Figure 2. Findings regarding the positive aspects of the curriculum and its implementation

The communicative approach of the curriculum was regarded positive as evidenced in the following quote: "The updated program helped us improve the learning process. We do not look for another approach as I believe that our students are learning English effectively by communicating with each other". (T1) The thematic approach was appreciated as it was believed to be useful to align various topics". (T3) Also, the curriculum's strength as addressing the needs of foreign language intensive secondary schools was emphasized: "Interactive teaching methods can be applied to foreign language intensive classes. In other classes, on the other hand, this is not possible" (T5).

Opinions regarding the suggested improvements

When the opinions of the English language teachers regarding the suggested improvements were analyzed, it was observed that they stressed eight main points, which are presented in Figure 3.

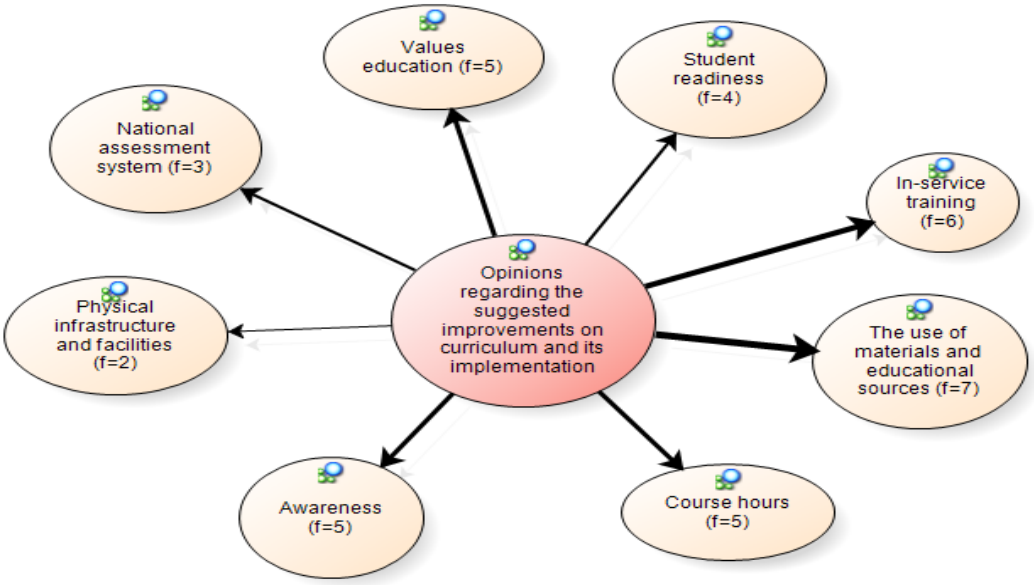

Figure 3. Findings regarding the suggested improvements on the curriculum and its implementation

The most salient weaknesses of the curriculum and, thus, areas of suggested improvement were that it lacked adequate support in terms of materials and educational sources. As one teacher puts it: "Limitations on the use of classroom materials are leading us into trouble. Compulsory books provided by the MoNE are insufficient. We always have to upgrade the content" (T1).

Another weakness of the curriculum was stated as the inadequacy of in-service training. One teacher said: "Teachers should take in-service trainings through which they will upgrade their knowledge and understanding of contemporary teaching methodologies" (T5). One notable suggestion showed the insufficient course hours stating that "I don't have enough time to realize communicative activities and improve my learners' communicative skills. Time is the most important problem as we have lots of objectives to cover in a very limited amount of time" (T1). Awareness, on the other hand, was said to be another weakness of the curriculum and thus an area of concern for the betterment. As one teacher remarked "In my opinion, the biggest problem is that students do not understand the necessity of learning English. Families also create a negative impact." The most frequent statement we hear is "Teacher! Why do we learn English? Let them learn Turkish" (T6). Values education, which was heavily emphasized in the updated curricula, represents another area of weakness that needs to be strengthened according to the participants. As one teacher emphasized "In my opinion, these values should be taught together with international values such as peace. In addition, students should have already started learning about these values in kindergarten. If not covered at earlier stages, values have no use other than appearing on bulletin boards. And I believe that they cannot be incorporated into English lessons" (T2).

In Class Observations

A structured observation form examining if main components of the curriculum were considered in actual classroom teaching was used to analyze lessons. The observation aimed at indicating if the upgraded curriculum was sufficiently implemented in realized classroom practice by indicating if dimensions were incorporated fully, partly or were not integrated. Findings of the observation form are presented in Table 9 (Appendix 1).

As seen in Table 9, lack of incorporation of dimensions requested in the curriculum prevails for all class levels and various variables inspected. While the density is lower at the sixth grade, in grades 5, 7 and 8, it is clear that the alternative "no" dominates the whole observation scale. It became evident that at all four class levels, activities and values were not adequately aligned. In addition, structural and linguistic elements of the language were addressed as separate topics, and values such as friendship, justice, honesty, self-control, patience, etc. were inadequately addressed. Furthermore, students were not led to use various learning strategies, and they could not transfer their knowledge of English into different contexts. Finally, product-oriented assessment techniques such as tests and written quizzes were emphasized. At three class levels (fifth, seventh and eighth grades), it was observed that in-class materials did not cover key competences and values stressed in the curriculum, and class time was mostly used to cover topics stated in the curriculum rather than strengthening communication. In addition, students were not given opportunities to listen or speak by generating language practice resembling authentic contexts, and they learned about the language rather than doing something with it. Materials were not developed from authentic sources, and the implementation of the curriculum was not adequately actualized. On the other hand, at one class level (sixth grade), communication was completely conducted in English, and for two other levels (seventh and eighth grade), it was partly conducted in English. However, this communication was one sided-from the teacher to the students.

At two class levels (sixth and eighth grades), it was observed that cultural elements were partly incorporated into classes. On the other hand, at the fifth and sixth grade levels, listening and speaking skills were addressed; however, techniques such as drama and role-play were not adequately used. At the seventh and eighth grade levels, it was observed that alignment among the various courses by means of the thematic approach was unsuccessful, and reading and writing skills were partly used. Finally, a positive aspect that was observed for all class levels was that the students were provided with materials to strengthen their prior learnings.

DISCUSSION

Employing Stake's (1967) congruence-contingency model, it was found out in the present study that the updated secondary school EFL curriculum and its implementation by English language teachers lacked consistency and congruence, in terms of intended and observed transactions. As a result of the questionnaire, it was found that teachers mostly held positive opinions on aims, content, learning experiences, evaluations and implementation dimensions of the updated secondary school English curriculum. Teachers welcomed that the curriculum emphasized communicative competence and that it focused on cultural elements as well as values. Teachers also welcomed interactive teaching methods and alternative assessment techniques. Interview results support the findings obtained from the questionnaire. Teachers who were interviewed stated that with the help of the updated curriculum, the communicative process could be further emphasized in classes, and they supported the use of theme-based instruction. The questionnaires and interview findings also indicated that teachers supported and tried to use the communicative approach in their classes. However, classroom observations revealed that in-class activities and implementations were not compatible with the demands of the communicative approach.

Findings of the present study are supported by previous studies. As Kırkgöz (2008) observed, teachers do not necessarily internalize and implement activities based on the communicative approach, and students do not actively participate in classes, particularly when they are teacher driven. In the present study, it was also found that communicative activities could not be successfully reflected in classroom practices; rather, they were based on knowledge transfer and structural elements of the language. These findings overlap with the findings of Coşkun (2011), who detected discrepancy between intended and realized classroom practices due to large class sizes, traditional grammar-based assessment and insufficient time to prepare communicative materials. Findings also support the study of Denkci Akkaş and Coker (2016) who found out that English language teaching at the high school level in Turkey does not reflect the communicative language classroom depicted in the text of the national curriculum. Echoing Karavas (1993), it is worth noting that the communicative approach is observed at the theory level rather than in-class implementations. In this context, key competences in the curriculum were seldom reflected in class activities. As Kırkgöz, Çelik and Arıkan stated (2016), it is important to note that, even with the existence of a viable curriculum, successful implementation does not depend solely on the program itself, but on understanding and cooperation from all parties involved.

Although the questionnaire and interview findings showed that teachers were welcoming notions of cultural elements and values, the document analyses and observation findings revealed that neither cultural elements nor values were adequately reflected in classroom materials and course books. Naming one unit as "friendship", or incorporating Turkish private names into activities but concentrating on structural and linguistic elements in classes will only serve for perception management on paper rather than lead to a real change in the classes. As Kırkgöz, Çelik and Arıkan stated (2016), designing classroom texts and other teaching tools, materials designers must ensure that these resources can effectively serve as bridges between the program and the actual teaching context; and classroom teachers, with support from school administrators, must take an active stance in applying the suggested activities in the classroom.

While the questionnaire and interview findings showed that teachers found alternative assessment techniques useful and appropriate, in-class observations displayed that assessments were based on tests or quizzes comprising multiple choice and fill-in-the-blanks questions, or matching tasks. In the interviews, teachers highlighted that they mostly used multiple choice type assessments with eighth graders, since it is the type to most likely be used in the national high-stake examination to be taken by all students at the end of the eighth grade. In addition, as families reportedly wanted their children to enroll into better high schools via higher scores in the national examination, they urged the teachers prepare students for this exam rather than focusing on communicative methodologies and activities that

they perceived "game-like and childish". While such concerns were raised for eighth graders, classroom observations revealed that the case is not different at other class levels. For all levels, it was observed that assessment techniques, such as fill in the blanks, multiple choice or matching were commonly used. Thus, it is evident that structural and linguistic functions of language, rather than communicative competence, are being emphasized. Echoing Mickan (2013), an important problem in foreign language teaching is that assessment methods and techniques offered in the curricula, and the ones used during high stakes national examinations, which focus on grammatical accuracy and vocabulary knowledge, do not match. As Coleman noted (2009), prior to the national examination, both teachers and students concentrate on the exam content and, thus, the teaching-learning process turns exam driven. The present study finds support from the study of Özsevik (2010) who remarked that the main hindrance to the use of CLT in Turkey appears to be the grammar-based examination system. The researcher stated that the successful integration of CLT into English teaching in Turkey will only be possible if the examination system is amended in a way that will give the development of communicative skills the importance that it deserves.

The questionnaire results indicate that teachers mostly consider the given class hours inadequate. Numerous teachers stated that three hours for the fifth and sixth grades, and four hours for the seventh and eighth grades are not adequate, and within this period, it is impossible to cover all the objectives stated in the curriculum. The interviewed teachers also stated the same inadequacies for the sixth, seventh, and eighth grades. These findings are in line with the findings of Aksoy, Bozdoğan, Akbaş and Seferoğlu (2018). Kandemir (2016) similarly stated that teachers found class hours inadequate.

Another salient finding of the present study is the lack of in-service training offered to English language teachers. Only eight teachers among the 96 answering the questionnaire, and one among seven of the interviewees stated that they got in-service training on the updated curriculum or contemporary teaching methodologies. It is clear that an updated curriculum brings with it new approaches, methodologies and assessment techniques. In this case, teachers who are assigned to enact the updated curriculum, require in-service training based on all the updates. Although the interviewed teachers stated that the newly recruited teachers need such in-service programs, classroom observations revealed that all English language teachers need to upgrade themselves in terms of the updated curriculum. As stated by the interviewed teachers, these trainings need to be in the form of workshops, to be delivered in real class cases. Echoing Aksoy (2019), such in-service training programs need to be practice-oriented and continuous. Within this context, it is clear that English language teachers need training on how to use the communicative approach effectively in their classes.

The present study is supported by previous studies dealing with the theory-practice link stating that curriculum reforms or updates stay on the paper but are not transferred to in-class practices (Butler, 2011; Fitzpatrick, 2011; Kırgkőz, 2008). The results of the present study also support the findings of Erarslan (2019), who found that curricula changes in Turkey, related to primary school English language teaching programs, fall short of meeting the demands of the country and global world in terms of equipping learners with the necessary communicative skills in English. The researcher concluded that class hours are limited for teachers to cover the program content, exerting undue pressure on the part of the teachers and suggested that the factors which hamper the process of language teaching and learning in a negative way have to be handled and addressed carefully by the decision makers, program developers and other agents, such as education planners.

It seems impossible to reflect the desired philosophy of any curriculum, unless teachers internalize that philosophy and become proficient users of the methodologies required by the curriculum. Thus, it is critical that teachers get support in form of in-service training on how to actualize the curriculum updates.

CONCLUSION

Resorting to Stake (1967), the present study found that there is a lack of congruence and contingency among the intended and observed transactions within the scope of the updated secondary school curriculum. Considering that there is a remarkable gap between what is intended and what is carried out, first, a national foreign language policy document should be prepared, and a unique foreign language-teaching system for the needs and realities of Turkey should be targeted. Second, the updated English language curriculum needs to be evaluated countrywide. In addition, it is evident that English language teachers need in-service training on the use of the communicative approach as well as technology use and authentic materials preparation. This can be achieved by a large-scale protocol establishment between MoNE and a couple of universities who excel in teacher training. On the other hand, MoNE needs to be supported in terms of writing better and more effective course books. In addition, the intensive English education at some fifth-grade levels need to be disseminated, and English instruction should be further extended and incorporated into the sixth, seventh and eighth grades. Finally, if the national examination at the end of eighth grade continues, then the grading/scoring of the English section needs to be equalized with that of the math or science sections, and a variety of question types, including alternative assessment methods, needs to be established.

Limitations

The findings of this study are limited to data gathered from 96 English language teachers who participated in answering the questionnaire, seven English language teachers who were interviewed, and four classroom observations at different secondary school levels. Thus, the findings cannot be easily generalized to the whole population. However, it is believed that this study has detected critical aspects that impede a more fully implementation of the prescribed EFL curriculum for secondary schools in Turkey. Further studies will contribute to a deeper understanding of the gap between theory as expressed in curricular documents, teachers' views on curricular changes and realized practices.

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REFERENCES

Ağçam, R., & Babanoğlu, M.P. (2018). The solo analysis of EFL teaching programs: Evidence from Turkey. *Turkish Studies-Educational Sciences, 13* (27), 1-18. DOI: 10.7827/TurkishStudies.14255

Aksoy, E., Bozdoğan, D., Akbaş, U., & Seferoğlu, G. (2018). Old wine in a new bottle: Implementation of intensive language program in the 5th grade in Turkey. *Eurasian Journal of Applied Linguistics 4*(2), 301–324. DOI: 10.32601/ejal.464187

Aksoy, E. (2019). Developing a modular in-service training program to improve teaching skills of primary school teachers of English in Turkey. *International Journal of Curriculum and Instruction, 1*(1), 141–171.

Butler, Y. G. (2011). The implementation of communicative and task-based language teaching in the Asia-Pacific Region. *Annual Review of Applied Linguistics, 31*, 36–57. DOI: 10.1017/S0267190511000122

Büyükduman, F.İ. (2005). The opinions of elementary school English teachers on the English curriculum for elementary schools. *Hacettepe University Journal of Education, 28*, 55–64.

Carless, R. D. (2004). Issues in teachers' reinterpretation of a task-based innovation in primary schools. *TESOL Quarterly, 38*(4), 639–662. DOI: 10.2307/3588283

Cheserek, G. J., & Mugalavi, V. K. (2012). Challenges and reforms facing Kenyan education system in the 21st century: Integrating the principles of vision 2030 and constitution 2010. *Journal of Emerging Trends in Educational Research and Policy Studies, 3*(4), 471–478.

Coleman, H. (2009). *Indonesia's 'international standard schools': What are they for?* Paper presented at the 8th Language and Development Conference, Dhaka, Bangladesh.

Coşkun, A. (2011). Investigation of the application of communicative language teaching in the English language classroom – a case study on teachers' attitudes in Turkey. *Journal of Linguistics and Language Teaching, 2* (1).

Daloğlu, A. (1996). *A case study on evaluating the "certificate for overseas teachers of English" curriculum at Bilkent University.* (Unpublished doctoral dissertation). Middle East Technical University

Demirlier, H. (2010). *Students' and teachers' attitudes towards the newly developed curriculum of primary schools.* (Unpublished master's dissertation). Muğla Sıtkı Koçman University.

Denkci-Akkas, F., & Coker, B. (2016). The use of communicative approach in 9th grade EFL classes. *Eurasian Journal of Educational Research, 65*, 71-90. DOI:10.14689/ejer.2016.65.05

Dinçer, B. (2013). *Evaluation of 7th grade English language curriculum according to Stufflebeam's CIPP model.* (Unpublished Doctoral dissertation). Adnan Menderes University.

Dinçer, B., & Saracaloğlu, A.S. (2018). Evaluation of 7th grade English language curriculum based on Stufflebeam's CIPP model according to teachers' views. *Turkish Studies-Educational Sciences, 13 (19), 561-588.* DOI: 10.7827/TurkishStudies.14139

Er, K. O. (2006). Evaluation of English curricula in the 4th and 5th grade primary schools. *Ankara University Journal of Faculty of Educational Sciences, 39*, 1–25.

Erarslan, A. (2019). Factors affecting the implementation of primary school English language teaching programs in Turkey. *The Journal of Language Teaching and Learning*, *9*(2), 7–22.

Erbakan G. (2001). *Teachers opinions about primary schools' English program*. (Unpublished master's dissertation). Hacettepe University.

Erbilen Sak, O. (2008). *Evaluation of the English program for primary education according to teachers' opinions.* (Unpublished master's dissertation). Bolu Abant İzzet Baysal University.

Erdem, S., & Yücel Toy, B. (2017). Determination of the needs for foreign language oriented fifth grade English curriculum. *Turkish Studies, 12* (28), 259-280. DOI: 10.7827/TurkishStudies.12346

Erdoğan, V. (2005). *An evaluation of the English curriculum implemented at the 4th and 5th grade primary state schools: The views of the teachers and the students*. (Unpublished master's dissertation). Mersin University.

Fitzpatrick, D. (2011). *Making sense of the English language policy in Thailand: An exploration of teachers' practices and dispositions.* (Unpublished doctoral dissertation). University of Exeter.

Fraenkel, J.R., Wallen, N. E., & Hyun, H.H. (2012). *How to design and evaluate research in education* (8th edition). New York: McGraw-Hill.

Gözütok, D. (2001). Program değerlendirme [Program evaluation]. In Mehmet Gültekin (Ed.), *Öğretimde planlama ve değerlendirme* [Planning and evaluation in instruction] (p.p 175–190). Eskişehir: Anadolu Üniversitesi Yayınları.

Hamid, M. O., & Honan, E. (2012). Communicative English in the primary classroom: Implications for English-in-education policy and practice in Bangladesh. *Language, Culture and Curriculum, 25*(2), 139–156. DOI: 10.1080/07908318.2012.678854

Kandemir, A. (2016). *An evaluation of 2nd grade English curriculum within a participant-oriented program evaluation approach.* (Unpublished master's dissertation). Pamukkale University.

Karavas, E. (1993). *English language teachers in the Greek secondary school: A study of their classroom practices and their attitudes towards methodological and materials innovation.* (Unpublished doctoral dissertation). University of Warwick.

Kırkgöz, Y. (2008). A case study of teachers' implementation of curriculum innovation in English language teaching in Turkey primary education. *Teaching and Teacher Education, 24*(7), 1859–1875. DOI: 10.1016/j.tate.2008.02.007.

Kıkgöz, Y., Çelik, S., & Arıkan, A. (2016). Laying the theoretical and practical foundations for a new elementary English curriculum in Turkey: a procedural analysis. *Kastamonu Education Journal, 24* (3), 1199-1212.

Mickan, P. (2013). *Language curriculum design and socialization.* United Kingdom, UK: Multilingual Matters.

Miles, M. B., & Huberman, M. A (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.

MoNE (2013). *İlköğretim kurumları ingilizce dersi (2, 3, 4, 5, 6, 7 ve 8. sınıflar) öğretim programı [Primary and secondary school (grades 2-8) English language curriculum]*. Talim ve Terbiye Kurulu Başkanlığı [Board of National Education]. Retrieved from https://dyned33.files.wordpress.com/2013/02/ingilizce_2-8.pdf on 15 May 2019.

MoNE (2018). *İngilizce dersi öğretim programı 2-8. [English language curriculum of grades 2-8]*. T.C. Millî Eğitim Bakanlığı [Ministery of National Education]. Retrieved from

http://mufredat.meb.gov.tr/Dosyalar/201812411191321-%C4%B0NG%C4%B0L%C4%B0ZCE%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI%20Kl as%C3%B6r%C3%BC.pdf on 15 May 2019.

İlköğretim ve eğitim kanunu ile bazı kanunlarda değişiklik yapılmasına dair kanun [Primary Education Law] (2012). Official Gazzette (28261). Retrieved from https://www.resmigazete.gov.tr/eskiler/2012/04/20120411.htm on 15 May 2019.

Ornstein, A. C., & Hunkins, F. P. (2016). *Curriculum: Foundations, principles, and issues* (7th edition). United Kingdom: Pearson Educational Leadership.

Ozsevik, Z. (2010). The use of communicative language teaching (CLT): Turkish EFL teachers' perceived difficulties in implementing CLT in Turkey. (Unpublished master's dissertation). University of Illinois at Urbana.

Stake, R. E. (1967). *The countenance of educational evaluation.* Retrieved from https://pdfs.semanticscholar.org/b07e/5b61cde550bfb0b64e895674a236c9003335.pdf on 15 May 2019.

Ültanır, G. (2003). *Eğitimde planlama ve değerlendirmede kuram ve teknikler [Theories and techniques in educational planning and evaluation].* Ankara: Nobel Yayın Dağıtım.

Varış, F. (1997). *Eğitimde program geliştirme [Curriculum development in education].* Ankara: Alkım Yayınevi.

Wang, H. (2006). *An implementation study of the English as a foreign language curriculum policies in the Chinese tertiary context.* (Unpublished doctoral dissertation). Queen's University, Belfast.

Yaacob, A. (2006). *Malaysian literacy practices in English: 'Big books', CD-ROMs and the year 1 English hour.* (Unpublished doctoral dissertation). University of Warwick.

Yüce, E. (2018). *Evaluation of the high school 9th grade English language curriculum of Turkey in relation to the CEFR principles*. (Unpublished doctoral dissertation). Hacettepe University.

Yücel, E., Dimici, K., Yıldız, B., & Bümen, N. (2017). An analysis of the primary and secondary school English language curricula published over the last 15 years. *Ege Journal of Education, 18* (2), 702-737. DOI: 10.12984/egeefd.305922

APPENDIX 1

Table 9.
Observation form regarding grade levels

	5th grade			6th grade			7th grade			8th grade		
	yes	partly	no	yes	partly	no	yes	partly	no	yes	partly	no
Materials used in class covered the key competences and values stated in the curriculum.			✓		✓				✓			✓
Activities used in class were aligned with values education.			✓			✓			✓			✓
Communication process was strengthened in class rather than trying to cover the linguistic structures.			✓		✓				✓			✓
Students were able to listen and speak in class just as they would in an authentic context.			✓		✓				✓			✓
Communication in class was carried out in English as much as possible.			✓	✓				✓			✓	
Communication process in class was used to create meaning.			✓			✓			✓			✓
Structural and linguistic elements of English were implicitly used rather than as separate topics.			✓			✓			✓			✓
Cultural elements were adequately addressed in class.			✓		✓				✓		✓	
Values such as friendship were addressed in class.			✓			✓			✓			✓
Students were led to use various learning strategies in class.			✓		✓				✓			✓
Students could transfer their knowledge and skills of English into every phase of learning.			✓		✓				✓			✓
Material support was provided to students to strengthen their prior learnings.	✓			✓			✓			✓		
Students could learn English by creating something with the language rather than learning about the language.			✓		✓				✓			✓
Rather than reading and writing, listening and speaking skills were emphasized at 5th and 6th grades.			✓		✓							
Reading and writing skills were adequately addressed at 7th and 8th grades.									✓		✓	
Teaching techniques such as drama and role-play were effectively implemented at 5th and 6th grades.			✓			✓						
Alignment among various courses was achieved by means of the Thematic approach offered at 7th and 8th grades.									✓			✓
Alternative assessment techniques were used rather than product-oriented techniques such as tests and quizzes.			✓			✓			✓			✓
Materials were developed and used from authentic sources to improve in-class communication process.			✓		✓				✓			✓
Implementation of the curriculum was effectively administered under current conditions.			✓		✓				✓			✓

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Türkiye'de 2017 yılında diğer derslerin öğretim programı yanında İngilizce öğretim programları da güncellenmiştir. Güncelleme kapsamında Avrupa Ortak Diller Metni Çerçeve Programı kapsamında yabancı dilin özgün iletişimsel bağlamda kullanımının amaçlandığı ve özellikle arkadaşlık, dürüstlük, adalet, sabır vb. değerler ile kültürel ögelerin program içeriğine yansıtıldığı ifade edilmiştir. Programlarda değerlendirme yöntemleri olarak ise öğrencinin kendi kendini değerlendirdiği öz değerlendirme ve akran değerlendirme gibi yöntemlerin ön plana çıktığı görülmektedir (MoNE, 2018).

Güncellenen programların sistematik bir şekilde değerlendirilmesi programın sürekliliği açısından son derece önemlidir. Programın etkililiğinin değerlendirilmesi, program geliştirme sürecinin ilk adımlarındandır (Gözütok, 2001; Ültanır, 2003). Kâğıt üzerinde güncellenen programların hedeflediği yeterliklere ve uygulamadaki etkililiğine ilişkin veri toplamak ve programı bu yönüyle değerlendirmek ise kuram-uygulama bağını sağlamanın önemli bir yöntemi olarak ortaya çıkmaktadır. Bu bağlamda reform adı altında gerçekleştirilen birçok program güncelleme çalışmasının gerçek uygulamalara yansımadığı ve kâğıt üzerinde kaldığını gösteren çalışmalar bulunmaktadır (Wang, 2006; Cheserek ve Mugalavi, 2012).

Mevcut çalışma güncellenen ortaokul İngilizce öğretim programlarının gerçek uygulamalar ile olan ilişkisini göstermesi bakımından son derece önemlidir. Bu kapsamda mevcut araştırmada Stake (1967)'in uygunluk-olasılık modeli kullanılarak beklenen ve gözlenen özellikler arasındaki uyum araştırılmıştır. Bu kapsamda yanıt aranan sorular şu şekildedir:

1) Öğretmenlerin programın; kazanımlarına, içeriğine, öğrenme-öğretme sürecine, değerlendirme sürecine, uygulamalarının etkililiğine ilişkin görüşleri nelerdir?

2) Güncellenen ortaokul İngilizce öğretim programının sınıf içi uygulamalara yansıması nasıldır?

Bu kapsamda araştırmada 2017 yılında güncellenen ortaokul İngilizce öğretim programlarının karma araştırma kapsamında doküman analizi, görüşme, yapılandırılmış anket ve sınıf içi gözlemler şeklinde dört farklı veri toplama aracı kullanılarak değerlendirilmesi amaçlanmıştır. Anket verileri Türkiye'nin farklı illerinde çalışan 96 İngilizce öğretmeninden toplanmış, görüşmeler Ankara ilinde bir devlet ortaokulunda çalışmakta olan 7 İngilizce öğretmeni ile yapılmış, sınıf içi gözlemler ise aynı ortaokulda dört farklı sınıf düzeyinde gerçekleştirilmiştir. Anket için kartopu örnekleme yöntemi, görüşmeler ve gözlemler için ise amaçlı örnekleme yöntemi benimsenmiştir. Araştırmada veri çeşitliliği sağlamak adına üçgenleme tekniği kullanılmıştır.

Araştırma kapsamında kullanılan ilk veri toplama aracı doküman analizidir. Bu kapsamda 2017 yılında güncellenen ortaokul İngilizce öğretim programı temel doküman olarak kullanılmıştır. Bununla birlikte örnek ders planları ve kullanılan materyaller de dokümanlar olarak incelenmiştir. Diğer veri toplama aracı olan yapılandırılmış anket iki bölümden oluşmuş ve ilk bölümde demografik bilgiler ikinci bölümde ise öğretmenlerin programın temel bileşenlerine ilişkin görüşlerini almak amacıyla yapılandırılmış ifadeler kullanılmıştır. Bu ifadelere öğretmenlerin evet, kısmen, hayır şeklinde yanıt vermeleri, hayır ve kısmen seçeneklerini işaretlemeleri durumunda ise bu durumun nedenlerini yazmaları istenmiştir. Yapılandırılmış görüşmeler üçüncü veri toplama aracını oluşturmaktadır. Bu kapsamda yapılandırılmış olan 11 soru 7 İngilizce öğretmenine yönlendirilmiş ve yaklaşık 30 dakika içinde sorulara yanıt vermeleri beklenmiştir. Öğretmenlerin anadilleri Türkçe olduğu için görüşme süreci Türkçe gerçekleştirilmiştir. Son veri toplama aracı olan gözlem formu ise güncellenen programda amaçlanan temel özellikler dikkate alınarak 20 madde şeklinde hazırlanmıştır. Gözlenmesi beklenen özellikler evet, kısmen ve hayır şeklinde kategorize edilmiş ve gözleme ilişkin detaylı not almak amacıyla her bir maddenin yanına açıklama bölümleri eklenmiştir. Gözlemler her bir sınıf düzeyinde

(5-6-7-8) birer saat olarak gerçekleştirilmiştir. Veri toplama sürecine ilişkin olarak gerekli izinler öncelikle Ankara İl Milli Eğitim Müdürlüğünden akabinde ise TED Üniversitesi İnsan Araştırmaları Etik Kurulundan alınmıştır.

Anket sonuçları öğretmenlerin güncellenen programın kazanımlar, içerik, öğrenme-öğretme süreci, değerlendirme ve sınıf içi uygulama boyutlarına ilişkin olumlu görüşlere sahip olduklarını göstermiştir. Programda iletişimsel yaklaşıma ve uygulamalara vurgu yapılmış olması, kültürel ögelere ve değerlere yer verilmiş olması öğretmenler tarafından memnuniyetle karşılanmıştır. Öğretmenler ayrıca etkileşimli öğretim yöntemleri ve alternatif ölçme-değerlendirme yaklaşımları konularında da olumlu görüş belirtmişlerdir. Görüşme yapılan öğretmenler de güncellenen programlar ile birlikte sınıflarında iletişim sürecinin daha yoğun vurgulandığını ve tematik yapılanmayı olumlu bulduklarını ifade etmişlerdir. Ayrıca EBA platformunu daha yoğun ve etkili olarak kullandıklarını ve okullarında uygulanan yabancı dil ağırlıklı program sayesinde iletişim sürecini güçlendirmek adına daha fazla zaman bulduklarını ifade etmişlerdir. Gerek anket gerekse görüşme bulguları öğretmenlerin iletişimsel yaklaşıma karşı olumlu bakışa sahip olduklarını ve bunu sınıflarına yansıtmaya çalıştıklarını göstermesi bakımından önemlidir. Bununla birlikte sınıf içi gözlemler programda amaçlanan iletişimsel yaklaşım uygulamalarının sınıf içi etkinliklere yeterince yansıtılmadığını ve sınıf içi iletişimin yabancı dil ile anlam oluşturmaktan çok dilbilgisi yapılarına odaklandığını göstermiştir. İletişim sürecinin çoğunlukla öğretmenden öğrenciye tek yönlü gerçekleştiği ve drama, rol oynama gibi iletişimsel tekniklerin yeterince kullanılmadığı da görülmüştür. Bu kapsamda araştırma bulguları alan yazındaki önemli birkaç araştırma bulgusunu destekler niteliktedir. Kırkgöz (2008) yaptığı çalışmada öğretmenlerin iletişimsel yaklaşım temelli etkinlikleri içselleştiremediğini, öğrencilerin ise çoğu öğretmen merkezli olan etkinliklere yeterince katılmadığını ifade etmiştir. Mevcut araştırmada da benzer şekilde öğretmenlerin yabancı dili anlam ve bağlam oluşturma amacı yerine dilin yapısal özellikleri üzerinde durdukları ve iletişim boyutunun büyük oranda göz ardı edildiği görülmüştür. Karavas (1993)'ın da işaret ettiği gibi iletişimsel yaklaşım sınıf içi etkinlik boyutunda gerçek uygulamalara yeterince yansımamış ve kuramsal düzlemde kalmıştır.

Diğer yandan gözlem yapılan sınıflarda etkinlikler ile temaların ve değerlerin yeterince ilişkilendirilmediği de görülmüştür. Programda belirtilen arkadaşlık, dürüstlük, adalet vb. değerlerin sınıf içi etkinliklerde herhangi bir yansıması gözlenmemiştir. Anket bulguları öğretmenlerin değerler konusunda ders kitapları ve materyallerindeki eksikliğe vurgu yaptıklarını göstermektedir. Bununla birlikte sınıf içi uygulama boyutunda öğretmenlerin ders kitabına bağlı kalmaları ve dilin yapısal özelliklerine vurgu yapmaları neticesinde değerlerin göz ardı edildiği ve uygulamalara yeterince yansımadığı söylenebilir. Ünitelerin temas bağlamında sunulmasının da benzer şekilde kâğıt üzerinde kaldığı ve yalnızca ünite adları ile ünite içerisinde geçen özel isimlerde vurgulandığı görülmüştür. Gerek tema yapılanması gerekse programda vurgulanan değerlerin uygulamaya yansıtılamaması daha kapsamlı olarak yapılacak başkaca çalışmalarda ele alınabilir. Diğer yandan gerek anket gerekse görüşme bulguları programlarda vurgulanan alternatif ölçme-değerlendirme yaklaşımlarını öğretmenlerin faydalı ve gerekli bulduklarını göstermiştir. Bununla birlikte sınıf içi uygulamalara bakıldığında çoktan seçmeli, boşluk doldurmalı, eşleştirmeli soru türlerinin yoğun bir şekilde kullanıldığı gözlenmiştir. Özellikle 8. sınıf düzeyinde öğrencilerin yılsonunda girecekleri ulusal çoktan seçmeli sınav dolayısıyla öğretmenlerin de standart çoktan seçmeli soru türünü kullanmak durumunda kaldıkları ifade edilmiştir. Bununla birlikte yapılan gözlemlerde diğer sınıf düzeylerinde de durumun farklı olmadığı ve çoktan seçmeli soru türünün yoğun bir şekilde benimsendiği görülmüştür. Bu kapsamda Mickan (2013)'ın da belirttiği gibi yabancı dil öğretimi sürecinde programlarda tanımlanan ölçme değerlendirme yöntem ve teknikleri ile ulusal çaplı sınavlarda sorulan soru türlerinin uyumsuzluğu önemli bir problem olarak göze çarpmaktadır.

Neticede anket ve görüşme sonuçları öğretmenlerin bakış açısıyla güncellenen programların uygun ve etkili olduğunu göstermekle birlikte, sınıf içi gözlemler kuram-uygulama bağını gerçekleştirmede kat edilmesi gereken bir hayli mesafe olduğunu göstermektedir. Dolayısıyla amaçlanan ile yapılabilen arasında önemli bir fark mevcut ise öncelikle bir İngilizce dil politika belgesi hazırlanması ve bu doğrultuda özgün bir yabancı dil öğretim ekosistemi amaçlanması gerekmektedir.

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Prospective mathematics teachers' critical thinking processes about scientific research: Newspaper article example

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ABSTRACT This study aimed to explore how prospective middle school mathematics teachers think critically about a newspaper article that reported the findings of a statistical research. Participants of the study were four fourth-year students enrolled at the mathematics teacher education program of a public university. To investigate the research question of the study, case study method was employed. In-depth semi-structured interviews were done to examine participants' critical thinking processes. The findings of the study indicated that prospective mathematics teachers made use of a variety of critical thinking processes (comprehending, making connections, inferring ideas, critiquing, and self-reflecting) and provided clues about the interrelated nature of these processes. This study would shed light on the characterization of critical thinking in the context of statistical literacy by suggesting a blended framework. It also suggests the design of the tasks including media articles to promote both statistical literacy and critical thinking in statistics education courses for prospective mathematics teachers.

Keywords: *Critical thinking, Mathematics education, Media texts, Statistical literacy, Teacher training*

Matematik öğretmeni adaylarının bilimsel araştırma hakkındaki eleştirel düşünme süreçleri: Gazete haberi örneği

ÖZ Bu çalışmanın amacı, ortaokul matematik öğretmeni adaylarından istatistiksel bir araştırmanın bulgularını sunan bir gazete haberini okumaları istendiğinde öğretmen adaylarının nasıl eleştirel düşündüklerini incelemektir. Çalışmanın katılımcıları bir devlet üniversitesinde öğrenim gören dört son sınıf ortaokul matematik öğretmeni adayıdır. Araştırmanın amacına uygun olarak, durum çalışması yönteminden yararlanılmıştır. Çalışmanın ana veri toplama kaynağını, öğretmen adaylarıyla yapılan görüşmeler oluşturmaktadır. Yarı yapılandırılmış görüşmeler aracılığıyla katılımcıların eleştirel düşünme süreçleri derinlemesine incelenmiştir. Bu çalışmanın bulguları, ortaokul matematik öğretmeni adaylarının bilimsel araştırma içeren bir gazete haberini okurken çeşitli eleştirel düşünme süreçlerinden (anlama, bağlantı kurma, çıkarım yapma, eleştirme ve yansıtıcı düşünme) yararlandıklarını ortaya koymaktadır. Aynı zamanda bu eleştirel düşünme süreçlerinin birbirleriyle ilişki olduğuna dair ipuçları sunmaktadır. Bu çalışmanın, istatistiksel okuryazarlık bağlamında eleştirel düşünmenin tanımlanmasına ilişkin harmanlanmış bir teorik çerçeve sunarak, istatistik eğitimi ve eleştirel düşünme çalışmalarına ışık tutacağı öngörülmektedir. Ayrıca bu çalışma, matematik öğretmeni adayları için istatistik eğitimi derslerinde hem eleştirel düşünme hem de istatistiksel okuryazarlığın geliştirilmesi için medya metinleri içeren ders içeriklerinin geliştirilmesini önermektedir.

Anahtar Sözcükler: *Eleştirel düşünme, İstatistiksel okuryazarlık, Matematik eğitimi, Medya metinleri, Öğretmen yetiştirme*

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INTRODUCTION

Parallel to the rapid progress in science and technology, new skills and literacies relevant to the challenges of 21st-century have been emphasized by many educators. School systems around the world are being encouraged to consider the development of such literacies and skills in their curricula (e.g., Jacobs, 2010; Wagner, 2014). One of the important skills for individuals in an information society is *statistical literacy* (Gal, 2002; Gould, 2017), which has a significant role in being individuals who evaluate claims and arguments and make effective decisions in their life (Moore, 1998). Today, individuals are surrounded by an enormous amount of information from diverse sources. Many of the information individuals reach involve statistical aspects in them (Schield, 2004), which often include conclusions from statistical evidence. However, information released by these sources might be misleading and conflicting, and involve one-sided claims or arguments (Gal, 2002). To cope with such information, individuals need to critically review the information in the media texts before they develop ideas based on them. Otherwise, it would be difficult for individuals to develop sound ideas about the phenomena around them without having statistical literacy. Thus, statistical literacy is needed to make efficient decisions about social, political, economic and health issues in personal life and in workplaces, rather than blindly adopt misleading information released in the media texts (Gal, 2002).

Studies on statistics education put emphasis on the use of real-life contexts in teaching and learning of statistics (Ben-Zvi & Garfield, 2008; Gal, 2002; Utts, 2003; Watson, 1997). In this sense, media texts such as newspaper articles can be considered as a tool for supporting students' statistical literacies in context, since they often involve statistical information regarding daily life issues (Watson, 1997). In order to help students to develop a critical perspective about statistical information around them, instead of merely dealing with computations, students can be asked to interpret and critically question the information presented in the media (Watson, 1997). In addition, Jarman and McClune (2007) suggested that teachers can use the media texts to alert students to be aware of the strengths and limitations of such reports in the context of scientific literacy, which focuses more on critical reading of scientific issues (e.g., genetics, astronomy, energy) and scientific research process. In this sense, the construct of *critical thinking* can be considered as a valuable phenomenon to consider in studying statistical education.

Critical thinking has been emphasized as an educational goal by various researchers (e.g., Ennis, 1985; Facione, 1990; Halpern, 1998; Kennedy, Fisher, & Ennis, 1991; Kuhn, 1999; Paul, 1984; Siegel, 1988). Critical thinking has been considered as one of the primary goals of education since people need to be active critical citizens in the society (Kennedy et al., 1991) and to cope with misleading or fallacious information in the social and scientific texts (Lin, 2014; Norris & Phillips, 2012; Vieira & Tenreiro-Vieira, 2016). In spite of such an emphasis, several studies on statistical thinking pointed out that students mostly have lack of statistical and mathematical knowledge to comprehend scientific research in the media articles and tend to receive information conveyed in the articles without any criticism (Watson, 2006). In the future, to nurture students as critical thinkers in schools, an important first step is to train prospective teachers as individuals who can think critically. If teachers have lack of statistical knowledge and critical sense while reading real-life contexts, it would hinder students' development of statistical literacy (Watson, Callingham, & Nathan, 2009). Various curriculum documents also put emphasis on the importance of thinking critically in the out-of-school contexts such as media texts (Australian Education Council [AEC], 1991; Ministry of National Education of Turkey [MoNE], 2018; National Council of Mathematics Teachers [NCTM], 2000).

It should be noted that, in order to provide students with effective learning experiences that help them to think critically on statistical concepts, schools rely on mathematics teachers' knowledge and skills (Batanero & Diaz, 2010; Burrill & Biehler, 2011; Chesler, 2015). In Turkey and other countries (e.g., the US, New Zealand) the mathematics curriculum was revised by paying attention to statistics education (Cantürk-Günhan, Bukova-Güzel & Özgür, 2012). Such attention on statistics, as a new learning domain of mathematics education, requires prospective teachers' training and revision of current statistics courses in teacher education programs. Even if the curriculum documents emphasize and gave attention to statistics education, learning of statistics depends on the teachers' capacity. However, most of the teachers do not have sufficient experiences in learning of statistics (Zhang & Stephens, 2016), particularly, prospective mathematics teachers who are future teachers of statistics in the school mathematics (Gattuso & Ottaviani, 2011). In teacher education programs prospective teachers were mostly taught statistics by mathematics educators who have not been particularly trained in statistics education (Batanero, Burrill, & Reading, 2011). They were often taught about theoretical statistics in introductory statistics courses and there is need for professional training of mathematics teachers to teach statistics (Batanero & Diaz, 2010). Prospective teachers should be prepared to teach statistics concepts and statistical literacy (Batanero, Burrill, & Reading, 2011; Burrill & Biehler, 2011**)**. Teacher education programs should start to provide opportunities of instructional practices of statistics and development of thinking skills (statistical and critical thinking) (Aizikovitsh-Udi, Kuntze, Clarke, 2016). Teachers should be trained to be critical thinkers about the use of statistics in media contexts (Chesler, 2015) and have pedagogical content knowledge to promote students' critical thinking and use of statistics in real-life contexts (Watson & Nathan, 2010). In spite of such an emphasis and concerns on mathematics teacher education programs, there has been very few studies on teacher education on this issue (Chesler, 2015). In-depth investigation of critical thinking processes of prospective mathematics teachers who are taught in the current teacher education programs would be a crucial initial step for training of prospective teachers in teaching statistics, particularly in the context of statistical literacy. It would, in turn, reflect deficiencies in teaching of statistics in teacher education programs and shed light into design of the statistics courses.

There have been scarce studies on investigation of prospective teachers' critical thinking in the media texts; but also, on interpretation of critical thinking in the context of statistical literacy even though they are related constructs (Budgett & Pfannkuch, 2010; Gal, 2002; Watson & Callingham, 2003). Critical thinking and its components have been often described from the philosophical, psychological, and cognitive perspectives in education by various researchers (e.g., Ennis, 1985; Facione, 1990). However, there is need for describing critical thinking in the context of statistics education (Kuntze, Aizikovitsh-Udi, & Clarke, 2017), particularly statistical literacy, which is highly related construct with critical thinking (Gal, 2002). This study addresses this gap by investigating how prospective mathematics teachers think critically about a media text involving scientific research and by adapting theoretical framework of critical thinking to the statistical literacy context. To achieve this goal, we made use of critical thinking framework proposed by Facione (1990) as it provides comprehensive explanation of components of critical thinking, exemplify how strong critical thinkers think and it has potential to be transferable to the different domains. In-depth investigation of prospective mathematics teachers' critical thinking processes based on a theoretical framework would be a crucial step to address the problem discussed above, which would in turn enlighten the design of the statistics courses in teacher education programs. In this regard, we aim to investigate the following question:

How do prospective middle school mathematics teachers think critically when they are reading a scientific research published in a newspaper article?

Conceptualization of Critical Thinking

Critical thinking and its components were defined by several researchers (Ennis, 1985; Facione, 1990; McPeck, 1990; Paul, 1984). Ennis (1985) defined critical thinking as "reflective and reasonable thinking that is focused on deciding what to believe or do" (p. 45). He identified the characteristics of individuals who think critically through several cognitive skills (e.g., thinking about the quality and

credibility of arguments, drawing conclusions with a carefulness, clarifying ideas appropriately) and dispositions (e.g., being open to alternatives, making an effort to be informed). Similarly, Paul (1984) defined critical thinking based on mastery of skills and dispositions such as being autonomous, persevering, and open minded to avoid egocentrism. Facione (1990), in a further study, proposed a comprehensive framework including cognitive skills and dispositions based on the consensus among forty-six experts. These cognitive skills include interpretation, analysis, evaluation, self-regulation, inference, and explanation and their subskills. He also reported a list of dispositions (e.g., being open-minded, willing to search for truth, being alert to use critical thinking), supportively previous studies on critical thinking.

Studies on critical thinking highlighted a clear agreement among researchers on the components of critical thinking as a blend of skills and dispositions. However, there has been a disagreement on whether these skills are generalizable to other domains or they should be subject-specific skills and cannot be generalized (ten Dam & Volman, 2004). This disagreement among researchers is not scope of this paper. This study holds a view compatible with the study of Facione (1990) in which he suggested critical thinking could be transferred to a wide range of subject matter domains. We made use of the critical thinking framework proposed by Facione (1990) as a guide to identify prospective mathematics teachers' critical thinking processes when they were reading a scientific research conveying statistical information in a newspaper article, which were represented through using mathematical ideas such as percents or probability. In other words, this study involves the blending cognitive processes of critical thinking with statistical literacy required for making sense of media texts.

Critical Thinking and Statistical Literacy

In the statistics education literature, statistical literacy was defined by several researchers (delMas, 2002; Gal, 2002; Rumsey, 2002; Schield, 1999; Wallman, 1993; Watson, 1997). In this study, we focus on statistical literacy and look through the lenses of statistical literacy, particularly defined by Gal (2002). He defined statistical literacy as interpreting and critically evaluating claims or arguments in social and scientific texts and communicating about them. Several researchers proposed models to assess statistical literacy. They included critical thinking in their models of statistical literacy as a list of worry questions (Gal, 2002), as a last tier (questioning claims) (Watson, 1997), as the last stage (critical and critical-mathematical) in the hierarchical level of statistical literacy (Watson & Callingham, 2003), and as trigger elements (heuristics and fallacies and worry questions) (Budgett & Pfannkuch, 2010). The authors did not use the term of critical thinking explicitly in their conceptualization of statistical literacy. They included some components of critical thinking such as questioning claims and using mathematical and statistical knowledge to interpret the claims. Even though they included some points on critical thinking, they did not discuss what critical thinking refers to and how it could be defined in a comprehensive way in the context of statistical literacy.

In the critical thinking literature, several research reports emphasized the role of statistical knowledge in critical reading of the texts (Ennis & Weir, 1985; Facione, 2011; Halpern, 1998). For example, Ennis and Weir (1985) in their essay test on critical thinking included essays directly related with statistics to measure students' judgment level. These essays required students to recognize bias in the essays, sampling, and causality. Halpern (1998) also included two categories directly related to statistics in her taxonomy of critical thinking skills: (1) thinking as hypothesis testing (e.g., considering sample size, generalizability) and (2) understanding likelihood and uncertainty to make decisions (p. 452). Recently, Facione (2011) also pointed out that people should think about the extent to which inductive arguments could be generalizable with taking into account of some statistical concepts (e.g., sample representativeness and sampling), know the difference between correlation and causality, and recognize overgeneralizations and exaggerated numbers. Even though the focus of these studies is not on the statistics and probability, they provide some instances of the relationship between critical thinking and statistical literacy. The studies on statistical literacy and critical thinking provide clues about interrelated nature of critical thinking and statistical literacy. It provides motivation for

conducting this study and investigating critical thinking in the context of statistics education. In the current study, in order to contribute to the conceptualization of critical thinking in statistics education, prospective teachers' analyses of a newspaper article that include statistical information were investigated through the lenses of critical thinking framework proposed by Facione (1990).

METHODOLOGY

The case study was employed to investigate prospective mathematics teachers' critical thinking processes when they were asked to read a scientific research published in a newspaper article. The reason of the case study was in-depth examination of fourth-year prospective mathematics teachers' critical thinking processes, who were on the brink of graduation from teacher education program and completed statistics and probability and research methods courses.

Participants

Participants of the study were four prospective middle school mathematics teachers. They were selected among 38 fourth-year students who were enrolled in an undergraduate teacher education program of a public university in Turkey. After graduation, they become candidates to work in middle schools as mathematics teachers for grade levels 5 to 8. The teacher education program requires all students to take a course on Probability and Statistics as well as on Research Methods. In order to select the participants, researchers asked 38 fourth-year students, who were volunteered to participate to the study, to write down their reflections about statistical information in a newspaper article that is only used for participant selection. Four participants were chosen with respect to their potential to provide rich data by reflecting their thinking, tend to express their ideas with valid mathematical procedures, and detect critical points in the article in order to gain insight into their critical thinking processes. Four participants were willing to participate to the interviewing process. In the current study, they were given pseudonyms, namely Ali, Meltem, Melek, and İrem. All participants were majoring in mathematics education. In addition, Ali and Meltem had minor in statistics as a secondary domain and İrem had minor in mathematics department.

Data Collection

Semi-structured interviews were conducted to elicit prospective teachers' thinking processes in detail. Interviews were audio and video recorded, and lasted for forty-five minutes approximately. Participants were asked to read a newspaper article (Appendix 1) that Watson (2011) suggested to use it in classrooms. This article, reported in the Mercury newspaper of Tasmania, was about fidelity and infidelity of women and men ("Cheat radar better tuned in men, study finds", 2008). The language of original newspaper article was in English. It was translated into Turkish by the researchers and participants were asked to read this translated version.

The article involves probabilistic and statistical statements, especially related with conditional probability concept (Table 1). To make their thinking process visible, researchers asked some key questions about the article: "*What is the main idea of the newspaper article? What conclusions did researchers reach according to newspaper article? What conclusions could you draw from the text? How could the researchers conduct the study reported in the newspaper article? (e. g. how to select sample, how to collect and analyze the data, how to reach reported findings) How would you evaluate reported findings? What do you think about generalizability of the reported statistics in the newspaper article?*" In addition to these questions, researcher particularly asked participants what they understand from four statements (Table 1) in the newspaper article to gain insights into their thinking processes.

The statements particularly involve conditional probability concept and they were expressed as percentages, which is one of the representations of probability (Gal, 2005) and requires proportional reasoning. Their thinking processes were elaborated through follow-up questions such as *How can you express the statements mathematically? How could such a conclusion be reached? and How do you calculate it*?"

Table 1.
Statements in the newspaper article

Statements	
Statement 1	"The results, published in New Scientist, show 29 per cent of men admitted they had cheated compared with 18.5 per cent of women."
Statement 2	"Researcher Paul Andrews said men were better at judging fidelity than women. 'Eighty per cent of women's inferences about fidelity or infidelity were correct, but men were even better, accurate 94 per cent of the time' Dr. Andrews said."
Statement 3	"Men were more likely to catch out a cheating partner, picking up on 75 per cent of the reported infidelities compared with 41 per cent discovered by women."
Statement 4	"Men are better at detecting a cheating partner than females, and they are more likely to suspect infidelities that do not exist."

Data Analysis

Data analysis was conducted to investigate the indicators of prospective middle school mathematics teachers' critical thinking processes about statistical information in the newspaper article. The framework proposed by Facione (1990) was used to identify critical thinking processes. In order to organize prospective teachers' thinking about statistical information, we made use of the statistical literacy frameworks of Gal (2002) and Watson (2006). In subsequent sections, we present briefly how we used existing frameworks on critical thinking and statistical literacy. These frameworks were used as a starting point to analyze the data. They were not entirely applicable to the context of our study. Thus, we made refinements to make them suitable with our data analysis, which resulted in a blended version of the frameworks of critical thinking and statistical literacy. We made some adaptations and refinements regarding some dimensions of the frameworks without making significant changes in the meanings of concepts.

Adaptation of Critical Thinking Framework to the Context of Statistics and Probability

In this study, we organized participants' responses about statistical information in the newspaper article at three broad dimensions: *Base of reported findings*, *reported findings*, *generalizability of reported findings.* In order to identify the participants' critical thinking instances, we adopted the framework developed by Facione (1990) using Delphi Method from the experts on critical thinking. They identified six cognitive skills of critical thinking and their sub-skills: Interpretation (categorization, decoding significance, clarifying meaning), analysis (examining ideas, detecting arguments, analyzing arguments), evaluation (assessing claims, assessing arguments), inference (querying evidence, conjecturing alternatives, drawing conclusions), explanation (stating results, justifying procedures, presenting arguments) and self-regulation (self-examination, self-correction) (p. 12). They highlighted that listing of the skills is not intended to indicate any order or hierarchical. Whereas some of them may overlap to each other, some skills may be prerequisite for the others in different contexts. We included all of the dimensions in the original framework, except the dimension of "explanation," since it was not observed in the data of our study. The reason why it was not observed in this study was due to the fact that "explanation" skill in the original framework was about presenting research results in a coherent way and justification of the claims or arguments concerning them. In this study participants read the statistical results already written by others and published in the newspaper article. Thus, they did not need to write or present statistical results and arguments about them. The other dimensions of the Facione's framework (1990) were included in the current

study. We made revisions in the sub-dimensions to make them more suitable with the context of this study. They were restated respectively as the following: comprehending, making connections, inferring, critiquing, and self-reflecting. At the end of the data analysis process, we identified five interconnected critical thinking processes, which is resulted in a blended framework of critical thinking and statistics in the context of media texts. Each dimension with their brief explanations are presented in Table 2.

Table 2.
Codes for analysis of critical thinking processes concerning statistics and probability

Critical thinking skills	Sub-skills of critical thinking	Examples
Comprehending	Identification of the main idea of the text	Determining the purpose of the reported study and distinguishing main idea or purpose of the text from extraneous or irrelevant ideas in the newspaper article
	Organization of the contextual information	Constructing graph, table, diagram, or other visual displays that show relationships between variables or findings of reported study in the newspaper article, classifying information with the consideration of their attributes
	Clarification of the information	Restating or paraphrasing the words, phrases, and statements in the newspaper article, recognizing ambiguous or vague terms of the research that are crucial to understand the nature of reported study, making the meanings of the statements explicit, particularly with the use of confusing language of conditional probability
Making Connections	Examining links between ideas	Identifying the statements, ideas, concepts, expressions that are related to each other, identifying similarities and differences between findings of the reported study, searching for the prerequisite finding to understand another reported finding and relating it with that finding, breaking up results or conclusions of reported study into smaller parts or results
Inferring	Examining evidence	Exploring the background information to make inference about the reported study, seeking information about sample, sample selection, and population that needs to be conveyed to make sense of generalizability of the reported findings
	Proposing alternatives	Suggesting alternatives regarding sampling with the consideration of advantages and disadvantages of each alternative and considering alternative sample sizes to draw proper conclusions, formulating alternatives of the research design for reported study when background information is missing
	Drawing conclusions	Educing new reasonable verbal or numerical conclusions by using relevant information about the reported study, reaching new proportions or calculations from the probabilistic statements or percentages, making inferences about reported study (e.g., generalizability) with the consideration of relevant statistical information (e.g., representativeness of the sample, sample size, random sampling)
Critiquing	Detecting misleading information	Detecting conflicting information or author's overgeneralization, considering all aspects of conclusions of the reported study rather than just considering one side of them, interrogating how the data of reported study is collected, possible bias in measurement, recognizing the statements or reported statistics in a given context which contradict with each other
	Recognizing factors of credibility	Paying attention to crucial concepts of statistics (e.g., sample size, representativeness of sample, sampling, chance variability, inference from sample to population) to judge the credibility of the findings, considering critical factors concerning generalization of findings in the article (e.g., random sampling, sample size, research design, confounding variables, sample representativeness)
Self-Reflecting	Expressing own strengths and weaknesses	Reading the article a few times to be sure if one did not notice something important and questioning own personal beliefs or attitudes, expressing how one makes assessment based on personal ideas and admitting own weaknesses when one critiques the reliability of the results or conclusions in the article
	Making corrections or revisions	Correcting own mistakes after examining own thinking process and looking back where one made mistakes or has inadequacies, making corrections in calculations or interpretations

Organization of Statistical Information in the Newspaper Article

In this study, we organized participants' responses about statistical information in the newspaper article at three broad dimensions: *Base of reported findings*, *reported findings*, *generalizability of reported findings* in the newspaper article. The first, base of reported findings, includes information about the origin of reported research in the newspaper article. In his study Gal (2002) explained in the categories of "knowing why data are needed and how data can be produced" and "knowing how statistical conclusions or inferences are reached." On the basis of the categories in the Gal's model, we described the base of reported findings in the context of media texts as the background of the study including sampling process, data collection and data analysis processes, and report of findings. Background of the study mentioned in the newspaper article was not explicitly given, as in most the other articles. The second dimension of reported findings in the newspaper article refers to the descriptive or summary statistics such as percentages, mean, graphs and tables. As Gal (2002) and Watson (2006) explained, basic notions in statistics and probability include concepts such as average, chance, or representation of data in tables or charts in the context of statistical literacy. Newspaper articles mostly reports such descriptive information about research study. The last dimension is related to generalization of the findings reported in the newspaper article. This dimension mostly emerged from the data. In his study Gal (2002) also suggested adults at least intuitively make connections between how data is produced and how statistical conclusions are made and generalized. In this study, generalizability of reported findings refers to intuitively making sense of the extent to which reported findings are generalizable to the population or other similar contexts and identify crucial factors related to generalization such as sampling, sample size, sample representativeness, confounding variables, confidence interval, and design of the study.

FINDINGS

Findings regarding participants' critical thinking processes were organized under three headings of statistical information conveyed in the newspaper article: Critical thinking concerning (1) bases of reported findings, (2) reported findings, and (3) generalizability of reported findings.

Critical Thinking about the Bases of Reported Findings in the Newspaper Article

This section presents participants' critical thinking processes about the bases of the reported findings in the newspaper article. Base of the reported findings is regarded as background information of the study such as sampling, data collection and analysis process, and how results are interpreted and reported**.** Some of this information is not explicitly conveyed in the newspaper article.

Regarding sampling process, only one of the participants (Ali) mentioned the role of sample and its representativeness while judging the credibility of the study in the article. The other participants only stated the sample size of the reported study as it was written in the newspaper article (203 women and 203 men, or 406 people). Ali, at least intuitively, questioned how the sample size could have a role in making inferences from the sample to population. During this process, he proposed to consider the samples with different sizes such as 20 couples and 2000 people. He considered strengths and drawbacks of each sample size to make accurate inferences from the study:

203 couples, actually, the number is good. It gives considerable information, that is, it is neither 1 nor 2. Well, if this study had been conducted with 20 couples, the answers would not have been all that good, the extreme properties of those 20 people would have emerged. As the sample size increases, the power of the representativeness of the sample also increases. If this research had been conducted with 2000 people, we would state that it was more generalizable and more accurate.

Participants' thinking process about data collection revealed that all participants concentrated on the what was measured in the questionnaire and what kind of questions were asked to the participants of reported study in the newspaper article, which is reported as the following statement: "*Researchers at Virginia Commonwealth University in Richmond gave confidential questionnaires to 203 young couples, asking them whether they had ever strayed, and they suspected or knew their partner had*.". Although two participants just restated the questions, other two participants attempted to clarify their meanings. Meltem, for example, clarified one of the questions in the questionnaire, "*whether they [subjects in the reported study] had ever strayed*". She stated as "*I thought that it was a question about past relationship. The article could have just said like this: the young couple could have been informed that this study was about their current relationship.*" In order to clarify its meaning, she added the expression of current relationship to the question of "have you ever cheated" and removed the ambiguity in the question. Moreover, Ali attempted to critique a possible bias in data collection process based on a statement in the article, "*29 per cent of men admitted that they had cheated compared with 18.5 per cent of women*". He argued that subjects of the reported study might give deceptive information about their cheating situation by stating "*Are men better confessors or do men cheat [their partners] more? It is unclear. Some might cheat [their partners] and says they didn't [cheat]; that's why, I think this may not give an idea about who cheat more*."

Another finding related to the bases of reported finding was that all participants attempted to comprehend data analysis process of the reported study by reconsidering how data could be organized through categories. They intuitively identified variables of gender (women and men) and cheating (their predictions on partners' cheating and real situation on cheating) even though they did not explicitly used the term of variable. They suggested to compare the prediction and real situation. It was only İrem who reflect more comprehensive thinking process regarding data analysis of the reported study. While thinking about the statement of "*Eighty per cent of women's inferences about fidelity or infidelity were correct, but men were even better, accurate 94 per cent of the time*.", she constructed a table that shows the possible categories in the reported study in order to comprehend data analysis process of the study (Figure 1).

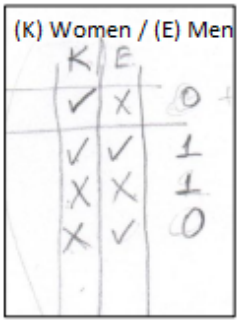

Figure 1. İrem's categorization of variables (gender, fidelity and infidelity inferences) to illustrate data analysis

The last main finding was about how the results in the article were reached and reported. Participants initially did not have any concern about the results reported in the newspaper, which conveys information about only women and men's correct inferences about their partners' cheating situation. They just restated the reported results in the article. Then, they made an effort to judge the results of the study in the newspaper article when they were particularly asked to critique the results. However, they mostly made subjective judgments. For example, Melek reflected on her thinking process while reading the media text. She expressed how she evaluated the results reported in the article stating "*When thinking about the article, I think I'm adding my opinions a little. I'm looking at the claims made at the beginning and the numbers below, I'm comparing them. Even if I am not doing calculations… If it fits my line of thought, I believe it more*." During this process she compared the differences between results that are represented as numerical values of 80% and 94%, and 75% and 41% in the newspaper article and related them with the claim of the article. On the other hand, İrem was more critical about the results in the reported study after she constructed tables that organize the raw data (Figure 2). She realized the role of sample size in each category on determining credibility of

the results besides whole sample size. To illustrate, she compared the number of subjects in each category and realized sample sizes (139 and 163), in the categories of women/men right inferences when their partners did not cheat them, were higher than the other categories. She stated as follows "*If the number of people who are cheating had been higher than 29%, the ratio of 41% would change possibly…there are much more people in the category of "women/men not cheating and their partner inferences right*".

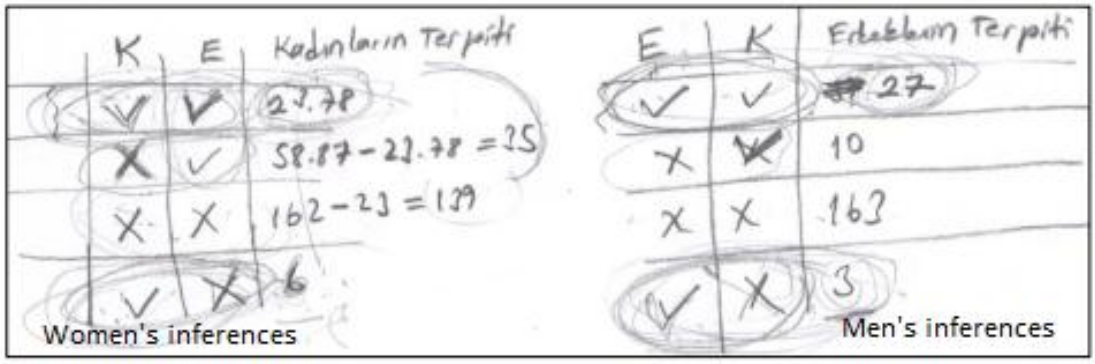

Figure 2. İrem's organization of the findings in the article through tables

To summary, participants made use of several interrelated critical thinking processes. They mostly comprehended and critiqued information that is already given in the newspaper article rather than missing information in the article, and also reflected on their own thinking processes. In fact, the newspaper did not provide complete information regarding reported study (e.g. how data were analyzed, reliability of the results, all findings emerged from the survey). The participants mostly did not question the missing information (women and men's wrong inferences about their partners' cheating) in the article.

Critical Thinking about the Reported Findings in the Newspaper Article

This part presents participants' critical thinking concerning four probabilistic statements in the newspaper article (Table 1), which involve descriptive or summary statistics such as percentages. Analysis of participants' thinking processes about reported statistics indicated that students attempted to comprehend the meanings of these statements, made connections between them to comprehend their meanings, inferred new conclusions from the statements that were not stated in the article, and during these processes they reread the article to make sure whether they understood the statements correctly (self-reflecting). There are four main findings that arise from this study.

The first main finding is related to Statement 1, which conveys information about the number of men and women who admit they were cheating their partners. Participants tried to comprehend the meaning of the Statement 1. Three of them restated it with different words on the basis of their calculations. They calculated the number of men and women who admit they were cheating by making link with another sentence in the article which gives information how many men and women participated to the reported study (203 couples). That is, they restated the Statement 1: "*The results, published in New Scientist, show 29 per cent of men admitted they had cheated compared with 18.5 per cent of women*". Melek, for example, clarified the meaning of Statement 1 through proportional reasoning (Figure 3). She explained as follows "*There are 59 men and 38 women who admit they cheated on their partners*".

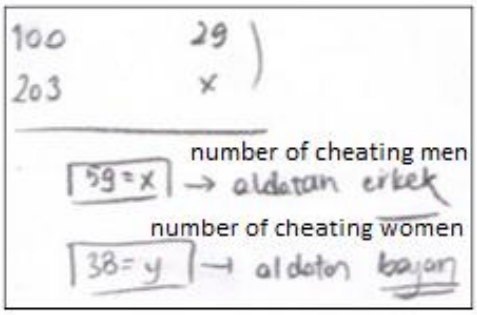

Figure 3. Melek's clarification of the meaning of Statement 1 through proportional reasoning

The second main finding is related to Statement 2 and Statement 3, which are closely related with each other and require to understand the concept of percentage as a representation of likelihood in context of cheating. All participants tried to cope with clarification of these two statements to make sense them. For example, Melek had difficulty comprehending the Statement 2 and Statement 3 when she firstly read the article. She could not identify the difference between two statements, stating "*I could not understand these last two statistics (reads the last two paragraphs of the article). I think the meanings of the statements are the same. They are stated in the same way but with different values. Maybe there is a conflict here*." In a similar way, İrem had also trouble in comprehending the meanings of two statements when she firstly read them as stating "*Are they different? I don't know. I did not understand the concept of fidelity*". In further process, she had still confusions about the fidelity, but this time she attempted to solve the problem of uncertainty in its meaning when she was asked to specifically think about Statement 2. She questioned what infidelity and fidelity concepts mean:

I think I don't know the meaning of the concept 'fidelity'. I can't distinguish these two conditions [Statement 2 and Statement 3]. I think predicting [fidelity] correctly means when they say that they don't think their partner cheated on them, actually they [their partner] hadn't; and predicting infidelity correctly means when they say that their partner definitely must have cheated on them, their partner had done so.

İrem's thinking process became more sophisticated compared to that of Melek since she generated an idea about the meaning of the key terms in two statements and after that, she restated the Statement 2 numerically through proportional reasoning. She found how many men/women predict their partner's fidelity or infidelity correctly as in the following: "*162 women predicted correctly whether or not their partner cheated on them. And I understood that 190 men accurately predicted whether their partner cheated on them*." This thinking process indicates that İrem developed her clarification of Statement 2. However, she still had trouble in distinguishing the meaning of two statements. She could develop an idea about their differences when she was asked to specifically think about the Statement 3. She revised the Statement 3 by using numbers on the basis of certain calculations. However, she at first glance could not identify the conditional event of infidelity in the conditional statement of Statement 3: "*Men were more likely to catch out a cheating partner, picking up on 75 per cent of the reported infidelities compared with 41 per cent discovered by women*". In other words, she made calculations on the basis of all women and men rather the number of women and men cheating on their partners.

41 percent of 203 couples; so 83 women detected that their partner cheated on them. But there is something like this as well; 29 people admitted they had cheated their partners. I wonder whether 75% of %29 noticed cheating (reads the last paragraph again). According to the answers given, men noticed 75% of the cheatings done by their partners. I mean, it seems that 75% of cheating partners were noticed; but I made a mistake because I took 203 as a base.

For a while she recognized the Statement 1 that gives information about the number of men/women cheating and made a connection between Statement 1 and Statement 3 that are two closely related statements. In the process of examining connection between them, she revised the statements in the

article and reread them to make sure that she did not overlook any crucial information in the article. After reading the article again, she realized her mistake and realized the conditional event in the Statement 3. This process provides an evidence of her self-reflecting process by means of which she monitored her thinking process and made corrections in calculations regarding conditional probability. Interestingly other two participants (Ali and Melek) had a similar cyclic thinking process. At first glance they could not realize the condition in the Statement 3 as well. During this process, none of the participants explicitly express the term of conditional probability.

An important finding raised from this cyclic thinking process was that two prospective teachers created a table (İrem) and a diagram (Ali) to organize the reported findings through process the processes of comprehending and examining links between the statements in the article (e.g. comprehending the Statement 3 by making use of information in the Statement 1). Thus, it seemed that they could go further and draw new conclusions that are not stated in the article (e.g., percentage of men/women's wrong inferences about fidelity or infidelity, percentage of men/women wrong inferences about their partners' infidelity). For example, Ali expressed new inferences about the article in a diagram (Figure 4). It was also represented by the researchers in two-way tables to see what kind of inferences Ali made (Table 3). On the other hand, other two participants (Meltem and Melek) reached inaccurate conclusions or could not make further inferences.

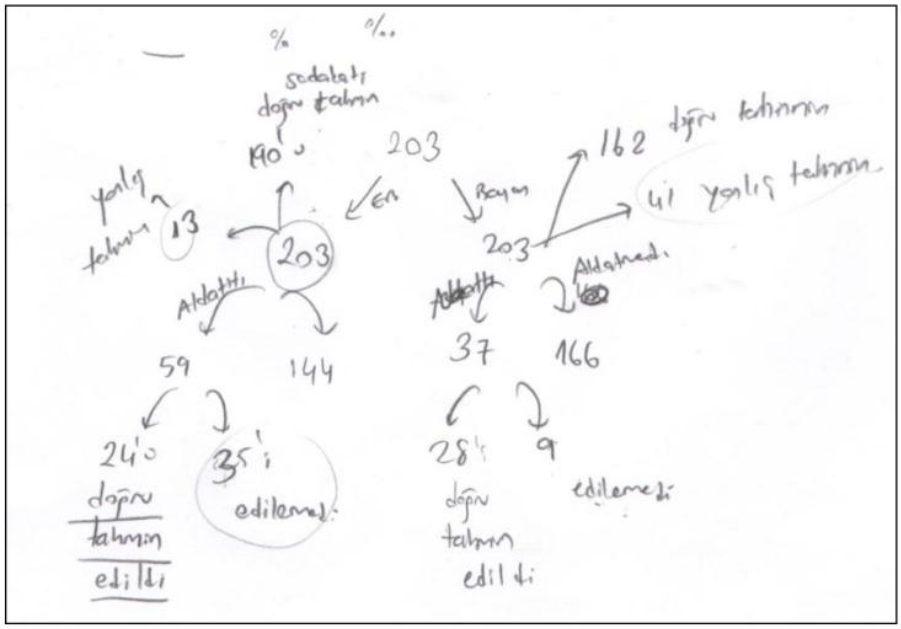

Figure 4. Ali's construction of a diagram like a tree diagram that show all possibilities

Table 3.
Male and females' inferences if their partners are cheating or not cheating in real life

		Partners' Cheating Situation in Real Life		
		Cheating	Not Cheating	Total
Male	Right Inferences	28	-	190
	Wrong Inferences	9	4	13
	Total	37	166	203
Female	Right Inferences	24	-	162
	Wrong Inferences	35	6	41
	Total	59	144	203

Note: Table was constructed by the researchers on the basis of Ali's diagram and his expressions.

The last main finding was related to Statement 4, which is a verbal statement related to the concept of conditional probability. This statement involves misleading information about the reported study. One would interpret the statement of "*They [men] are more likely to suspect infidelities that do not exist" in the article as "the probability of males' wrong inferences if their partners do not cheat is more than the probability of females' wrong inference if their partners do not cheat*". However, there is not a consistency between author's argument and the calculations made based on the numbers and percentages in the article. When the following calculations are made (Watson, 2011), it is found that female are more likely to suspect infidelities that do not exist, which uncover the misleading information in the Statement 4.

$$P\ (Male\ wrong\ inference/Female\ not\ cheating) = 3/165 = 1.8\%$$

$$P\ (Female\ wrong\ inference/Male\ not\ cheating) = 6/144 = 4.2\%$$

All of the participants overlooked this misleading information and could not detect it. However, only two (Ali and İrem) participants were worried about its meaning and attempted to criticize it. For example, in her critiquing process İrem had still confusions about the meaning of the verb of "suspect" and attempted to clarify its meaning. She proposed two alternative meanings for "being suspicious": (1) claiming his/her partner is cheating regardless of the fact that the partner is cheating or not cheating (2) claiming his/her partner is cheating; in fact, their partners are not cheating. On the basis of the second meaning, she made calculations and decided that Statement 4 conveys wrong information. She justified his thinking as stating "*If we think the second meaning that I believe in, women are more suspicious. That is, women are suspicious unnecessarily. I think it [Statement 4] is wrong. For men, 1.4% [3/203] and for women, 2.8% [6/203]*." Even though she thought the second meaning of the word is so meaningful that it fit with the meaning of Statement 4 and attempted to critique the credibility of Statement 4, she drew inaccurate conclusions by making use of relevant information in the table that she had constructed before (see Figure 2). She did not recognize the condition in the verbal statement of condition probability (the condition of men/women who are not cheating their partners). Instead she made calculations on the basis of the number of all participants (203) in the reported study.

In summary, there are four major findings regarding reported statistics (percentages and probabilistic statements): prospective mathematics teachers (1) had confusions about the meaning of the words or statements and making connections between statements; (2) had difficulty in understanding the meanings of the conditional probability statements and detecting conditional events in the statements; (3) reflected interrelated and cyclic process of critical thinking, particularly in conditional probability statements. This process was not so easy for prospective teachers, which required them to rethink about the meanings of words, review their calculations, reread the article, and correct their misunderstandings.

Critical Thinking about the Generalizability of the Reported Findings in the Newspaper Article

This part presents participants' thoughts about generalizability of reported findings, which requires at least intuitively to comprehend the extent to which reported findings can be generalizable to the population or other similar contexts. In the process of interviewing, participants were asked to think about to what extent the findings of the reported study could be generalizable. During this process, all of them had a tendency to critique the reported findings by recognizing several factors to determine generalizability of the reported study.

They focused on a variety of factors such as sample size (Ali, Meltem), background information about sample (residences, duration of marriage) (Ali, İrem), and sampling variability (İrem), confounding variables (İrem) and cultural factors (Ali, Melek). During critiquing process, two of the participants (İrem and Ali) differed from others since they searched for additional information (where participants

live, duration of marriage) that should have been explained in the newspaper article to make critiques about findings' generalizability.

Ali, for example, focused on the factors of sample size, how the sample is selected, and cultural factors to criticize if the findings of the study would be generalizable to a different culture. The following statements of Ali indicate that he firstly examined any evidence of sample's residence. Besides he proposed alternatives for conducting the study with more people (sample size) and people with different characteristics to make it more generalizable even though he did not reflect on the population of the reported study. It also seemed that he perceived the generalizability as getting similar results at different cultures such as Turkey. Therefore, he thought that the study is not generalizable to the context of Turkey and claimed the findings do not match with the context of Turkey based on his personal ideas.

Well, where was the research conducted? It hasn't been mentioned. The researchers did not mention from where they selected the couples. Did they choose them from the same place where the research was conducted? Maybe it is unique to that region. If this research had been conducted with more effort, with many more participants having different characteristics, I mean if they had conducted on many places, it would have been more reliable. So, I think we cannot generalize it to Turkey.

Similarly, İrem thought that this study is not generalizable. She paid attention to the factors of sample size and properties of sample in order to criticize the generalizability of the reported findings, as shown below. In the critiquing process, she examined any evidence regarding sample characteristics such as their residencies or countries and the duration of their marriage in order to make a reasonable decision about the generalizability of the reported findings.

Well, I don't know if 203 couples are enough. I don't think it can be generalized. My opinion, you can't imagine something big from a small sample. If I ask each of the 203 men or if I ask 58 men, in this case, will women predict only 29 percent of 58 men correctly? It seems that it will not be correct all the time. You know, different results will be obtained from different samples; well, here the 203 couples don't have any characteristic features anyway. I mean, where do they live, in which country, I don't know how long they have been married; maybe there are many influential factors. It has only mentioned that they are young couples.

During this process, it seemed that she intuitively had a sense of sample variability even though she did not express it in statistical terms. In other words, she seemed to intuitively appreciate the variability among the different samples chosen from the same population. However, she was still in the deterministic thinking process and was not sure if the sample size is large enough, stating "*You can't imagine something big from a small sample*".

Compared to Ali and İrem's thinking process, Meltem thought the reported study was generalizable. She supported her claim by comparing sample size with two alternative sample sizes (30 and 100) and concluded sample size is enough to make generalization, stating as "*203 is actually good number, in statistics when we, for example, carry out a study, we say it's a good result when it is over 30 or 100. Well, compared with that, 203 is good. It can be generalized because everything is clear*."

In summary, participants tried to critique the generalizability of the reported findings. Two of the participants (Ali and İrem) were more critical about generalizability and considered several factors (e.g., sample size, sample variability, sample characteristics concerning different cultures) and did not make immediate decisions about the generalizability. They also sought for background information to decide if it was generalizable. However, none of the participants reflected on the population of the study, random sampling, and representativeness of the sample concerning population while thinking about generalization from the sample in the reported study.

DISCUSSION AND CONCLUSION

This study examined prospective mathematics teachers' critical thinking processes when they were asked to read a scientific research reported in a media text. The analysis of prospective mathematics teachers' thinking process indicated that they made use of a variety of critical thinking processes ranging from comprehending to self-reflecting. This study also provided clues about related nature of critical thinking processes and their role in critical reading of media texts, which is regarded as the most easily accessible tool conveying statistical information to the public (Lin, 2014; Watson, 1995). For example, when prospective mathematics teachers were comprehending information in the media text, they made connections between statements in the article and had a tendency to question the meanings of the words or credibility of the statements. While inferring new conclusions/findings that were not stated in the article, two students (Ali and İrem) overviewed their thinking process and reread the article to check whether they understood the meaning of the statements correctly and made reasonable inference on the basis of their mathematical knowledge (e.g., proportional reasoning). This finding supports that skills of critical thinking are interrelated and also some skills could be executed by the use of other skills (Facione, 1990). In the statistics education context this finding implies that comprehending statistical information or making connections are as crucial as evaluating statistical claims in the newspaper articles. Interconnected use of critical thinking skills might tap use of different skills such as inferring ideas or critiquing information. In addition, as a remarkable finding, some skills of critical thinking became precondition for the use of other skills. For example, prospective teachers who could not clarify the meaning of the terms in the article and make connections between statements could not make further inferences from the article (Facione, 1990). In the current study, the newspaper article was originally presented to the participants without making any changes or manipulations. It might have crucial factor to elicit such an interrelated nature of critical thinking and its components in the context of statistics and probability.

The second major conclusion was that participants mostly made comments on existing information rather than missing information in the article (e.g., sampling, data analysis, data collection, missing findings). Newspaper articles might report lack of information or biased information about the reported study (McClune & Jarman, 2012). Thinking beyond the context, e.g. reading not only the existing information but also the missing information, is a crucial ability for being critical thinker while reading such media articles (Gal, 2002; Watson, 2006). In the current study, most of the prospective mathematics teachers focused on the sample size, which was the only information regarding sampling presented in the article. This finding was parallel with informal level of statistical literacy proposed by Watson and Callingham (2003) in which students consider a single aspect of statistical concepts. In addition, there were not sufficient information about data analysis and data collection processes in the article. Prospective teachers did not make sufficient comments particularly on data analysis. Newspaper articles does not often provide enough information about background of the study and this might lead to make hypothetical comments regarding original study and to have difficulty in discriminating the critique of the reported study from actual study (Budgett & Pfannkuch, 2010). Thus, prospective teachers in the current study might have had difficulty in making comments about actual study that does not exist in article. To make sound arguments about this finding, there is need for further studies. Such a problem in the newspaper article suggests the use of these kind of articles with the support of original research in the statistics education courses (Budgett & Pfannkuch, 2010; Gelman & Nolan, 2002). In the further studies, prospective teachers' critical thinking would be analyzed and compared in newspaper articles with different characteristics (with detailed information, without sufficient information) to decide what kind of newspaper articles could be used in the statistics education courses for mathematics teachers.

The third major conclusion was that during their first reading of the article, prospective mathematics teachers did not analyze critically the reported statistics (percentages, probabilistic statements) in the article and did not make inferences about them. They just restated what the article had already

reported. When they were asked to think about the meanings about the probabilistic statements through probing questions, it was revealed that prospective mathematics teachers had difficulty in identifying conditional events in the statements and they did not reflect on statistical concept (conditional probability) behind these statements even though they were taught about this concept in statistics education courses. Participants' difficulty in identifying conditional events is consistent with the findings of previous studies on conditional probability (Carnell, 1997; Falk, 1986; Stohl, 2005). This finding also suggests training of prospective mathematics teachers on learning and teaching statistics in real life contexts such as media article, which is particularly regarded as a natural way to introduce conditional probability concept (Watson, 1995). Moreover, prospective mathematics teachers who could use their mathematical and statistical knowledge (proportional reasoning, percentage, and creating two way-table or tree diagram) and comprehend statements effectively identified conditional events intuitively even though they did not realize them at first glance and use the term of conditional probability formally. This finding supports the previous studies on contingency table (Watson & Callingham, 2014) and tree-diagram (Böcherer-Linder, Eichler, & Vogel, 2017) including natural frequency that helped to comprehend conditional probability concept and discriminate the conditional events. Besides the use of displays in comprehending conditional probability concept, this study suggests statistics courses in mathematics teacher education encourage teachers to transfer of their mathematical and statistical knowledge to a variety of topics of media articles (e.g., health, politics, education, social life context) by giving enough time to think.

The fourth major conclusion was that participants conceptualized the generalization of findings as generalization from the sample to population or generalization from one context to another context. This finding is important to understand to what extent prospective mathematics teachers believe to the reported study and make decisions in their life. Prospective mathematics teachers critiqued the generalizability of the reported study based on a few statistical concepts (sample size and characteristics of the sample) or based on their personal ideas. This finding brings about the need for training of prospective mathematics teachers to analyze media texts reporting statistical research in a more comprehensive way. On the other hand, this study calls for training of mathematics teachers in statistics education to appreciate the nature of statistics and understand its difference from mathematics (Gattuso & Ottaviani, 2011) and design of statistics courses for prospective teachers (Watson & Moritz, 2002). The reason such a need is that one of the prospective mathematics teachers with a minor on mathematics department did not appreciate uncertain generalization from sample to population as stating "you can't imagine something big from small sample" when she was asked to think about the generalizability of the study. This finding could be interpreted as an evidence of which mathematics teachers could think the nature of statistics like mathematics. On the other hand, it might also be related to imbalance between critical thinking and statistical thinking as discussed by Kuntze, Aizikovitsh-Udi, and Clarke (2017). The prospective mathematics teacher's extreme criticism might have impeded their understanding of the nature of statistics and appreciation of uncertain generalization from sample to population.

The researchers and teachers who wants to reimplement this study in other contexts should consider several important points. One of the major points is that the prospective mathematics teachers in the current study were selected as having tendency to criticize the media article and took courses on statistics and research at their undergraduate program. In other words, they were already taught about key statistical concepts such as sample, sampling, variability, inference, and probability in the undergraduate program. Even so, they had some struggles in critical evaluation of media article as discussed above. However, the statistics courses in the undergraduate program did not involve use of newspaper article and interpreting statistical information in such contexts. Rather, it was based on teaching of concepts theoretically. Researchers and teachers should also consider that participants were given enough time to think about newspaper article and it was originally presented to the readers without making any changes on it. There was not time limitation for reading article and making judgments about the article. Lastly, this study presents the findings about prospective mathematics teachers' critical thinking processes related to one media text, which includes probabilistic statements about a social life context. Focusing on a particular concept and media article allowed in-depth

analysis by monitoring the flow of prospective teachers' thoughts. The reason of such a focus was also to present specific examples of blended theoretical frameworks of critical thinking and statistical literacy since the use of this framework is new and was adapted in the current study. Although focusing on one text provide in-depth examination of thinking processes, it would be also a limitation of the study. Thus, the findings of this study should be interpreted within its limitations such as the number of participants and its focus on an article including conditional probability concept in a social life context.

In conclusion, unique contribution of this study is twofold. First, this study showed that prospective mathematics teachers were in the processes of a variety of critical thinking processes ranging from comprehending to self-reflecting and each process of critical thinking has a crucial role to be critical thinkers in reading statistical information regarding a scientific research. Even though prospective mathematics teachers had completed statistics courses in the undergraduate education, they seemed to have difficulty in transferring their knowledge of statistics to the context of media texts and in making judgments by relating relevant concepts of statistics with a critical stance. Statistics has been often taught theoretically (Batanero & Diaz, 2010). The investigation of a media text and its adaptation to the statistics education allows researchers and teachers to relate statistics with daily life, which would, in turn, help to design and integrate such media tasks with the statistics courses in teacher education programs.

Secondly, this study contributes to the literature in terms of theoretical aspects. It does not only involve investigation of critical thinking processes in a particular context; but also, adaptation of critical thinking framework proposed by Facione (1990) to the context of statistics, which has been developed based on quantitative studies. Critical thinking has been often emphasized by the researchers in learning and teaching of statistical literacy. However, researchers have not paid attention to the elaboration of the concept of critical thinking in the context of statistics (Kuntze, Aizikovitsh-Udi, & Clarke, 2017). This study provides detailed exploration of critical thinking and its indicators in the context of statistical literacy through suggesting blended framework of critical thinking and statistical literacy. It has theoretical significance since it shows a case of how this framework works in the statistical literacy context. It would allow researchers to refine conceptualization of critical thinking by exploring interaction between critical thinking and statistical literacy and also to assess students' and teachers' critical thinking processes in the statistics education context. In further studies it could be elaborated and developed by using different topics of media texts (e.g., health, politics) including statistical studies with different methods (e.g., experimental, survey, correlational) and with data displays such as table and graphs.

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REFERENCES

Aizikovitsh-Udi, E., Kuntze, S., & Clarke, D. (2016). Connections between statistical thinking and critical thinking: A case study. In D. Ben-Zvi & K. Makar (Eds.), *The teaching and learning of statistics* (pp. 83-94). Cham, Switzerland: Springer. DOI:10.1007/978-3-319-23470-0_8

Australian Education Council (1991). *A national statement on mathematics for Australian schools*. Carlton, Victoria: Curriculum Corporation.

Batanero, C., Burrill, G., & Reading, C. (2011). Overview: Challenges for teaching statistics in school mathematics and preparing mathematics teachers. In C. Batanero, G. Burrill, & C. Reading (Eds.),

Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education: AJoint ISMI/IASE Study (pp. 407–418). New York: Springer. DOI: 10.1007/978-94-007-1131-0

Batanero, C., & Díaz, C. (2010). Training teachers to teach statistics: what can we learn from research? *Statistique et enseignement*, *1*(1), 5-20.

Ben-Zvi, D., & Garfield, J. (2008). Introducing the emerging discipline of statistics education. *School Science and Mathematics*, *108*(8), 355-361. DOI: 10.1111/j.1949-8594.2008.tb17850.x

Böcherer-Linder, K., Eichler, A., & Vogel, M. (2017). The impact of visualization on flexible Bayesian reasoning. *Avances de investigación en educación matemática, 11,* 25-46. DOI: 10.35763/aiem.v1i11.169

Budgett, S., & Pfannkuch, M. (2010). Assessing students' statistical literacy. In P. Bidgood, N. Hunt, & F. Jolliffe (Eds.), *Assessment methods in statistical education: An international perspective* (pp. 103–121). Chichester, UK: Wiley. DOI: 10.1002/9780470710470.ch9

Burrill, G., & Biehler, R. (2011). Fundamental statistical ideas in the school curriculum and in training teachers. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching statistics in school mathematics: Challenges for teaching and teacher education (A joint ICMI/IASE Study)* (pp. 57–69). New York, NY: Springer. DOI: 10.1007/978-94-007-1131-0_10

Cantürk-Günhan, B., Bukova-Güzel, E. & Özgür, Z. (2012). The prospective mathematics teachers' thought processes and views about using problem-based learning in statistics education. *International Journal of Mathematical Education in Sciences and Technology*, *43*(2), 145-165. DOI: 10.1080/0020739X.2011.592611

Carnell, L. J. (1997). *Characteristics of reasoning about conditional probability* (Unpublished doctoral dissertation). University of North Carolina, Greensboro.

Cheat radar better tuned in men, study finds. (2008, October 30). *The Mercury* (Hobart, Tasmania), p. 3.

Chesler, J. (2015). Reading the News: The Statistical Preparation of Pre-Service Secondary Mathematics Teachers. *Issues in the Undergraduate Mathematics Preparation of School Teachers*, *1*. Retrieved from https://eric.ed.gov/?id=EJ1061106

delMas, R. (2002). Statistical literacy, reasoning and learning: A commentary. *Journal of Statistics Education*, *10*(3). Retrieved from https://www.tandfonline.com/doi/full/10.1080/10691898.2002.11910679. DOI: 10.1080/10691898.2002.11910679

Ennis, R. H. (1985). A logical basis for measuring critical thinking skills. *Educational Leadership*, *43*(2), 44-48.

Ennis, R. H., & Weir, E. E. (1985). *The Ennis-Weir critical thinking essay test: An instrument for teaching and testing*. Pacific Grove, CA: Midwest Publications.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Research findings and recommendations* (ERIC Document Reproduction Service No. ED315423). Retrieved from https://eric.ed.gov/?id=ED315423.

Facione, P. A. (2011). *Think critically*. New York: Pearson Education, Englewood Cliffs.

Falk, R. (1986). Conditional probabilities: Insights and difficulties. In R. Davidson & J. Swift (Eds.), *Proceedings of the Second International Conference on Teaching Statistics* (pp. 292-297). Victoria, Canada: International Statistical Institute.

Gal, I. (2002). Adults' statistical literacy: Meaning, components, responsibilities. *International Statistical Review*, *70*(1), 1–25. DOI: 10.1111/j.1751-5823.2002.tb00336.x

Gal, I. (2005). Towards "probability literacy" for all citizens: Building blocks and instructional dilemmas. In G. A. Jones (Ed.), *Exploring probability in school. Challenges for teaching and learning* (pp. 39-63). Dordrecht, The Netherlands: Kluwer. DOI: 10.1007/0-387-24530-8_3

Gattuso, L., & Ottaviani, M. G. (2011). Complementing mathematical thinking and statistical thinking in school mathematics. In C. Batanero, G. Burrill & C. Reading (Eds.), *Teaching statistics in school mathematics-Challenges for teaching and teacher education: A Joint ICMI/IASE Study* (pp. 121-132). Springer. DOI: 10.1007/978-94-007-1131-0_15

Gelman, A., & Nolan, D. (2002). *Teaching statistics: A bag of tricks*. Oxford University Press. DOI: 10.1093/oso/9780198785699.001.0001

Gould, R. (2017). Data literacy is statistical literacy. *Statistics Education Research Journal*, *16*(1), 22-25.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains. *American Psychologist*, *53*(4), 449–455. DOI: 10.1037/0003-066X.53.4.449

Jacobs, H. (2010). *Curriculum 21: Essential education for a changing world*. Alexandria, VA: ASCD.

Jarman, R., & McClune, B. (2007). *Developing scientific literacy: Using news media in the classroom*. England, Open University Press.

Kennedy, M., Fisher, M. B. & Ennis, R. H. (1991). Critical thinking: Literature review and needed research. In L. Idol & B. F. Jones (Eds.), *Educational values and cognitive instruction: Implications for reform* (pp. 11-40). Hillsdale, NJ: Erlbaum. DOI: https://doi.org/10.4324/9781315044392

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher*, *28(*2), 16-25. DOI: 10.3102/0013189X028002016

Kuntze, S., Aizikovitsh-Udi, E., & Clarke, D. (2017). Hybrid task design: Connecting learning opportunities related to critical thinking and statistical thinking. *ZDM*, *49*(6), 923-935. DOI: 10.1007/s11858-017-0874-4

Lin, S. S. (2014). Science and non-science undergraduate students' critical thinking and argumentation performance in reading a science news report. *International Journal of Science and Mathematics Education*, *12*(5), 1023-1046. DOI: 10.1007/s10763-013-9451-7

McClune, B. & Jarman, R. (2012). Encouraging and equipping students to engage critically with science in the news: What can we learn from the literature? *Studies in Science Education*, *48*(1), 1–49. DOI: 10.1080/03057267.2012.655036

McPeck, J. E. (1990). Critical thinking and subject specificity: A reply to Ennis. *Educational Researcher*, *19*(4), 10-12. DOI: 10.3102/0013189X019004010

Ministry of National Education (2018). *Matematik Dersi Öğretim Programı (İlkokul ve Ortaokul 1-8. Sınıflar) [Teaching Program of Mathematics Course (Elementary and Middle School 1-8 Grades)]*. Ankara. Retrieved from http://mufredat.meb.gov.tr/Dosyalar/201813017165445-MATEMAT%C4%B0K%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI%202018v.pdf.

Moore, D. S. (1998). Statistics among the liberal arts. *Journal of the American Statistical Association*, *93*(444), 1253-1259. DOI: 10.1080/01621459.1998.10473786

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Norris, S. P. & Phillips, L. M. (2012). Reading science: How naive view of reading hinders so much else. In A. Zohar & Y. J. Dori (Eds.), *Metacognition in science education: Trends in current research* (pp. 37-56). Dordrecht, The Netherlands: Springer. DOI: 10.1007/978-94-007-2132-6_3

Paul, R. (1984). Critical thinking: Fundamental for education in a free society. *Educational Leadership*, *42*(1), 4-14.

Rumsey, D. J. (2002). Statistical literacy as a goal for introductory statistics courses. *Journal of Statistics Education*, *10*(3). DOI: 10.1080/10691898.2002.11910678

Schield, M. (1999). Statistical literacy: Thinking critically about statistics. *Of Significance*, *1*(1), 15-20. Retrieved from www.statlit.org/pdf/1999SchieldAPDU.pdf.

Schield, M. (2004). Information literacy, statistical literacy, data literacy. *IASSIST quarterly*, *28*(2-3), 6-11. DOI: 10.29173/iq790

Siegel, H. (1988). *Educating reason: Rationality, critical thinking, and education*. New York: Routledge. DOI: 10.1177/027046769101100128

Stohl (2005). Probability in teacher education and development. In G. Jones (Ed.), *Exploring probability in schools: Challenges for teaching and learning* (pp. 345- 366). Dodrecht: Kluwer. DOI: 10.1007/0-387-24530-8_15

ten Dam, G., & Volman, M. (2004). Critical thinking as a citizenship competence: Teaching strategies. *Learning and Instruction*, *14*(4), 359-379. DOI: 10.1016/j.learninstruc.2004.01.005

Utts, J. (2003). What educated citizens should know about statistics and probability. *The American Statistician*, *57*(2), 74-79. DOI: 10.1198/0003130031630

Vieira, R. M., & Tenreiro-Vieira, C. (2016). Fostering scientific literacy and critical thinking in elementary science education. *International Journal of Science and Mathematics Education*, *14*(4), 659-680. DOI: 10.1007/s10763-014-9605-2

Wagner, T. (2014). *The global achievement gap: Why even our best schools don't teach the new survival skills our children need and what we can do about it*. New York: Basic Books.

Wallman, K. (1993). Enhancing statistical literacy: Enriching our society. *Journal of the American Statistical Association*, *88*(421), 1-8. DOI: 10.1080/01621459.1993.10594283

Watson, J. M. (1995). Conditional probability: Its place in the mathematics curriculum. *The Mathematics Teacher*, *88*(1), 12-17.

Watson, J. M. (1997). Assessing statistical literacy through the use of media surveys. In I. Gal & J. Garfield (Eds.), *The assessment challenge in statistics education* (pp. 107-121). Amsterdam, The Netherlands: International Statistical Institute/ IOS Press.

Watson, J. M. (2006). *Statistical literacy at school: Growth and goals*. Mahwah, New Jersey: Lawrence Erlbaum Associates. DOI: 10.4324/9780203053898

Watson, J. M. (2011). Cheating partners, conditional probability and contingency tables. *Teaching Statistics*, *33*(3), 66-70. DOI: 10.1111/j.1467-9639.2010.00421.x

Watson, J., & Callingham, R. (2003). Statistical literacy: A complex hierarchical construct. *Statistics Education Research Journal*, *2*(2), 3-46.

Watson, J., & Callingham, R. (2014). Two-way tables: Issues at the heart of statistics and probability for students and teachers. *Mathematical Thinking and Learning*, *16*(4), 254-284. DOI: 10.1080/10986065.2014.953019

Watson, J., Callingham, R., & Nathan, E. (2009). Probing teachers' pedagogical content knowledge in statistics: "How will Tom get to school tomorrow?" In R. Hunter, B. Bicknell, & T. Burgess (Eds.), *Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 2, pp. 563-570). Adelaide: MERGA.

Watson, J. M., & Moritz, J. (2002). Quantitative Literacy for pre-service teachers via the Internet. *Mathematics Teachers Education and Development*, *4*(1), 42-55.

Watson, J., & Nathan, E. (2010). Biased sampling and PCK: The case of the marijuana problem. In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the future of mathematics education*. *Proceedings of the 33rd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 2, pp. 610-617). Fremantle, WA: MERGA.

Zhang, Q., & Stephens, M. (2016). Teacher capacity as a key element of national curriculum reform in statistical thinking: A comparative study between Australia and China. In D. Ben-Zvi and M. Makar (Eds.), *The Teaching and Learning of Statistics* (pp. 301-313). Cham, Switzerland: Springer. DOI:10.1007/978-3-319-23470-0_36

APPENDIX 1.

Cheat radar better tuned in men, study finds

WOMEN beware. New research shows men are better at detecting a cheating partner than females, and they are more likely to suspect infidelities that do not exist.

A U.S study of heterosexual couples found men are more suspicious, but an Australian sex researcher says they are only more suspecting because they are more likely to cheat.

"What we have here is a clear case of the pot calling the kettle black," said Sydney therapist Rosie King.

Researchers at Virginia Commonwealth University in Richmond gave confidential questionnaires to 203 young couples, asking them whether they had ever strayed, and whether they suspected or knew their partner had.

The results, published in New Scientist, show 29 per cent of men admitted they had cheated compared with 18.5 per cent of women.

Researcher Paul Andrews said men were better at judging fidelity than women.

"Eighty per cent of women's inferences about fidelity or infidelity were correct, but men were even better, accurate 94 per cent of the time," Dr. Andrews said.

Men were more likely to catch out a cheating partner, picking up on 75 per cent of the reported infidelities compared with 41 per cent discovered by women.

AAP MERCURY-3 Thursday, October 30, 2008

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Bilim ve teknolojideki hızlı ilerlemeye paralel olarak, 21. Yüzyılda ihtiyaç duyulan yeni beceriler ve okuryazarlık türleri birçok eğitimci tarafından ele alınmıştır. Bilgi toplumunda bireyler için önemli olan bu becerilerden biri, istatistiksel okuryazarlıktır (Gal, 2002; Gould, 2017). Bugün bireyler medyada çok çeşitli kaynaklardan bilgiye ulaşmaktadır ve bu bilgilerin çoğu istatiksel araştırmalardan bulgu ve sonuçlar içermektedir (Schield, 2004). Bireylerin medyadaki bu bilgileri kendi kanaatlerini oluşturmadan önce eleştirel olarak gözden geçirmeleri gerekir. Bu bağlamda, istatiksel okuryazarlığın, toplumda öne sürülen iddia ve argümanları sorgulayan ve etkili kararlar veren bir birey olmada önemli bir rolü vardır (Moore, 1998). Aksi takdirde, bireylerin, istatistiksel okuryazarlığa sahip olmadan çevrelerindeki olaylar hakkında sağlam fikirler geliştirmeleri zor olacaktır. Aynı zamanda, medyada yayınlanan bu bilimsel araştırmaların güçlü ya da sınırlı yanlarının farkına varılmasında eleştirel düşünmenin de önemli rol oynadığı vurgulanmıştır (Gal, 2002; Lin, 2014; Norris ve Phillips, 2012; Vieira ve Tenreiro-Vieira, 2016; Watson, 1997).

İstatistiksel okuryazarlık ve eleştirel düşünmenin önemine yönelik vurgulara rağmen, öğrencilerin çoğu medya haberlerinde yer alan bilimsel araştırmaları anlamlandıracak düzeyde istatistiksel ve matematiksel bilgiye sahip olmayıp, herhangi bir eleştiri yapmadan haberde verilen bilgilere inanma eğilimindedir (Watson, 2006). Öğrencileri toplumda eleştirel düşünen bireyler olarak yetiştirmek için atılacak ilk adım, geleceğin öğretmenleri ve toplumun birer vatandaşı olan öğretmen adaylarının eğitilmesidir. Eğer matematik öğretmenleri günlük yaşamda karşılaştıkları içerikleri okurken yeterince istatistiksel bilgiye ve eleştirel düşünceye sahip olmazsa bu durum öğrencilerin istatistiksel okuryazarlıklarının gelişimini engelleyebilir (Watson, Callingham ve Nathan, 2009). Bu yüzden öğretmenlerin istatistiğin günlük yaşam içeriklerinde kullanıma yönelik ve bu bağlamlarda öğrencilerin eleştirel düşünmesinin geliştirilmesi için pedagojik alan bilgisine sahip olmaları gerekmektedir. Fakat, ortaokul öğretmenlerinin istatiksel bilgileri günlük yaşama aktarmada zorluk yaşadıkları (Watson ve Nathan, 2010) ve medya haberlerinin sınıf içinde kullanımı konusunda yeterince özgüvene sahip olmadıkları ortaya çıkarılmıştır (Jarman ve McClune, 2007). Bu araştırmalar öğretmenlerin gazete haberi gibi günlük yaşam içeriklerini okurken derinlemesine bilişsel düşünme süreçlerinin incelemeye ihtiyaç olduğunu vurgulamaktadır. Bu araştırmalara ek olarak, Kuntze, Aizikovitsh-Udi ve Clarke (2017) hem istatiksel düşünme hem de eleştirel düşünmeyi hedefleyen etkinliklerin önemini vurgulayarak bu etkinliklerin tasarımına ihtiyaç olduğunu belirtmişlerdir.

Matematik öğretmeni adaylarının eleştirel düşünme süreçlerinin bir teorik çerçeve bağlamında incelenmesi bu amacı gerçekleştirmek için önemli bir adım olacağı düşünülmektedir. Bu bağlamda, bu araştırmada Facione (1990)'nin önermiş olduğu eleştirel düşünme teorik çerçevesini istatistiksel okuryazarlık bağlamına uyarlayarak, harmanlamış bir çerçeve ile şu araştırma sorusunun araştırılması hedeflenmiştir: "Ortaokul matematik öğretmeni adayları bir gazete haberinde yayınlanan bilimsel bir araştırmayı okurken nasıl eleştirel olarak düşünmektedir?"

Bu araştırma sorusuna yanıt aramak üzere, nitel araştırma yöntemlerinden biri olan durum çalışmasından yararlanılmıştır. Araştırmanın katılımcılarını bir devlet üniversitesinde öğrenim gören dört son sınıf matematik öğretmeni adayı oluşturmaktadır. Katılımcılar, 38 son sınıf matematik öğretmeni adayı arasından, bir gazete haberi ile ilgili sorulara verdikleri cevaplar doğrultusunda, (1) zengin veri sağlama potansiyellerine, (2) düşüncelerini geçerli matematiksel ifadelerle ifade etmelerine ve (3) haberde eleştirilecek kritik noktaları saptama eğilimlerine göre seçilmiştir. Katılımcılarla yapılan yarı yapılandırılmış görüşmeler bu çalışmanın veri toplama kaynaklarını oluşturmaktadır. Bu görüşmeler yaklaşık olarak 45 dakika sürmüştür. Katılımcılardan, Tazmanya Mercury tarafından yayınlanan (Ek 1), erkek ve kadınların sadakatleri üzerine yapılan bir bilimsel

araştırma içeren gazete haberini (Watson, 2011) okumaları istenmiştir. Bu gazete haberi özellikle koşullu olasılık kavramı ile ilgili olmak üzere istatistiksel bir araştırmanın sonuçlarını içermektedir. Bu gazete haberi ile ilgili katılımcılara belirli sorular sorularak (örn., Bu gazete haberindeki araştırmacı veriyi nasıl toplamış olabilir? Yayınlanan bu bulguları nasıl değerlendiriyorsun? Bu bulguların genellenebilirliği hakkında ne düşünüyorsun?) veri toplanması hedeflenmiştir.

Katılımcılarla yapılan derinlemesine görüşmeler, Facione (1990) tarafından önerilen eleştirel düşünme teorik çerçevesinden yararlanılarak analiz edilmiştir. Bu teorik çerçeve istatistik eğitimine, istatistiksel okuryazarlık ile ilgili modellerle (Gal, 2002; Watson, 2006) ilişkilendirilerek adapte edilmiştir. Bu istatistiksel okuryazarlık modelleri çerçevesinde gazete haberindeki istatistiksel bilgi üç ana başlıkta (yayınlanan bulguların arka planı, yayınlanan bulgular ve yayınlanan bulguların genellenebilirliği) organize edilmiştir ve bu üç başlığa göre öğretmen adaylarının eleştirel düşünme süreçleri incelenmiştir. Yayınlanan bulguların arka planı (base of reported findings), haberde verilen bilimsel araştırmanın nasıl yürütüldüğü (örneklem seçimi, veri toplama ve analizi, bulgular ve yorumlanması) ile ilgili olup çoğunlukla gazete haberlerinde sınırlı olarak sunulmaktadır. Yayınlanan bulgular (reported findings) ise, gazete haberine yansıtılan ve istatistiksel kavramlar (örn., yüzde, ortalama, olasılık) içeren ifadeler olarak tanımlanmıştır. Yayınlanan bulguların genellenebilirliği (generalizability of reported findings) ise yayınlanan bu bulguların örneklemden popülasyona ya da başka benzer bağlamlara ne derece aktarılabileceği ile ilgilidir. Eleştirel düşünme teorik çerçevesinde bazı değişiklikler yapılarak bu teorik çerçeve çalışmanın bağlamına uyarlanmıştır. Eleştirel düşünme süreçleri; anlama, bağlantı kurma, çıkarım yapma, eleştirme ve yansıtıcı düşünme olarak isimlendirilmiştir.

Verilerin analizi sonucunda üç temel bulguya rastlanılmıştır. İlk olarak, öğretmen adayları eleştirel düşünme süreçlerini iç içe geçecek şekilde kullanarak, gazetede verilmeyen eksik ifadelerden ziyade çoğunlukla gazetede var olan bilgileri anlamaya ve eleştirmeye çalışmıştır. Yayınlanan bulguların arka planı (örneklem seçimi, veri toplama ve analizi süreci, bulguların belirlenmesi ve yorumlanması) ile ilgili olarak sadece gazetede var olan bilgiler çerçevesinde yorum yapmışlardır. Gazetede örneklem büyüklüğü verildiği için, çoğunlukla örneklem büyüklüğüne odaklanmışlardır. Diğer öne çıkan bulgu ise, yayınlanan istatistiksel bulgularla (yüzde ve olasılık ifadeleri) ilişkilidir. Öğretmen adayları koşullu olasılık kavramı içeren ifadeleri anlamaya ve bu sırada bu ifadeler arasında bağlantı kurmaya çalışmıştır. Ancak sözel olarak yayınlanan bu ifadeleri anlamada ve eleştirmede oldukça zorlanmışlardır. Bu süreç, kelimelerin anlamı netleştirmeye çalıştıkları, birtakım hesaplamalar yaparak çıkarımlar yapmaya çalıştıkları ve bazı öğretmen adaylarının gazete haberini yeniden gözden geçirip hatalarını fark ettikleri iç içe geçmiş bir süreçtir. Son olarak, yayınlanan bulguların genellenebilirliğini iki öğretmen adayı daha çok eleştirme eğiliminde olup bu süreçte örneklem büyüklüğü, örneklemin özelliği, örneklem değişkenliği gibi kavramları, doğrudan bu terimleri kullanmasalar da göz önünde bulundurmuşlardır. Diğerleri ise, kendi kişisel görüşleri çerçevesinde çalışmanın genellenebilirliği hakkında görüşlerini ifade etmiştir. Buna ek olarak, öğretmen adayları bu süreçte popülasyon, örneklemin temsil edilebilirliği ve örneklem seçim metodu ile ilgili bir yorum yapmamıştır.

Bu çalışmada katılımcılar son sınıf matematik öğretmeni adayları arasından eleştirme potansiyellerine göre seçilmiş olmalarına ve istatistik ilgili çeşitli dersleri (istatistik ve olasılık, araştırma teknikleri) almalarına rağmen, yukarıda bahsedildiği gibi gazete haberini eleştirel olarak değerlendirmede sıkıntılar yaşamışlardır. Bu araştırmanın bulguları, okullarda istatistik kavramlarını öğrencilere öğretecek bireyler olarak matematik öğretmeni adaylarının medya haberleri gibi günlük yaşam bağlamlarında istatistiksel okuryazarlık ve eleştirel düşünmeye dair eğitimlere ihtiyaç olduğunu vurgulamaktadır. Çalışmanın sınırlılıkları (sınırlı sayıda katılımcı sayısı ve gazete haberi kullanımı) çerçevesinde, elde edilen bulguların ve eleştirel düşünme teorik çerçevesinin istatistiksel okuryazarlık bağlamında kullanılmasının istatistik eğitimi alanında gelecekte yapılacak çalışmalara ışık tutacağı öngörülmektedir.

EK 1.

Yapılan araştırmaya göre, erkekler eşinin aldattığını daha iyi tespit ediyor.

KADINLAR dikkat. Yeni yapılan bir araştırmaya göre, aldatan eşi tespit etmede erkekler kadınlardan daha iyi ve erkekler, var olmayan aldatmalardan şüphelenmeye daha eğilimli.

Amerika'da çiftlerle ilgili yapılan çalışma, erkeklerin daha şüpheci olduğunu buldu. Fakat, cinsiyetler üzerine çalışan Avustralyalı bir araştırmacı, daha çok aldatma eğiliminde oldukları için erkeklerin daha şüpheci olduklarını söylüyor.

Sydney'den terapist Rosie King "Buradaki durum, 'tencere dibin kara, seninki benden kara'nın açık bir örneğidir.' diyor.

Richmond'daki Virginia Commonwealth Üniversitesi'nden araştırmacılar, 203 genç çifte ait cevapların gizliliği korunacak şekilde hazırlanmış, anketler yoluyla eşlerini hiç aldatıp aldatmadıklarını, eşlerinin aldattığını bilip bilmediklerini ya da eşlerinden şüphelenip şüphelenmediklerini sordu.

New Scientist dergisinde yayımlanan sonuçlara göre erkeklerin yüzde 29'u aldattığını itiraf ederken, kadınlarda bu oran yüzde 18,5.

Araştırmacı Paul Andrews, "Kadınların eşlerinin sadakat ya da sadakatsizliği hakkında çıkarımlarının yüzde 80'i doğru. Ancak, erkekler yüzde 94'lük doğruluk oranıyla kadınlara göre daha iyi." diyerek erkeklerin, eşlerinin sadakatini yargılamada kadınlardan daha iyi olduğunu vurguluyor.

Verilen cevaplara göre, erkekler eşlerinin aldatmalarının %75'ini fark ederek, aldatmayı büyük bir olasılıkla tespit ederken, kadınlar aldatan eşlerinin %41' ini tespit ettiler.

AAP MERCURY-3, 30 Ekim Perşembe 2008

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Children's science learning outside school: Parental support

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ABSTRACT This study examined (a) the availability of basic science materials in children's home environment, (b) the frequency of parents' involvement in informal science activities with their children, (c) the level of opportunities parents offered their children for learning basic science subjects, and (d) the effect of grade level on parental support for children's science learning. In this cross-sectional survey study, data were collected from 735 parents in a city in the north region of Turkey. Results revealed that most children did not have basic science materials at home. Parental support for making science trips was especially low. The parents supported their children's learning most in the area of health, security, and nutrition. The MANOVA results indicated that the parents of middle school children supported their children significantly less to do science and nature activities compared to the parents of preschool and elementary school children. The middle school children were also less likely to be supported by their parents to learn science subjects related to matter, energy, and livings compared to preschool children. The parents of preschool children offered more opportunities for their children to learn science subjects related to sky compared to the parents of elementary and middle school children.

Keywords: *Parental support, Science learning, Science outside school*

Çocukların okul dışı fen öğrenmeleri: Aile desteği

ÖZ Bu çalışmada (a) basit fen materyallerinin çocukların ev ortamında bulunup bulunmadığı, (b) ailelerin çocuklarıyla birlikte informal fen etkinliklerine katılım sıklığı, (c) temel fen konularını öğrenmeleri için ailelerin çocuklarına sundukları fırsatların düzeyi ve (d) çocukların öğretim düzeyinin ailelerin fen öğrenmeleri için çocuklarına sağladıkları destek üzerindeki etkisi araştırılmıştır. Bu kesitsel tarama çalışmasında veriler, Türkiye'nin kuzey bölgesindeki bir ilde yaşayan 735 veliden toplanmıştır. Bulgular çocukların çoğunluğunun ev ortamında temel fen materyallerine sahip olmadıklarını göstermiştir. Özellikle bilim gezilerine katılmaya ilişkin olarak ailelerin çocuklarını destekleme düzeyi düşük bulunmuştur. Ailelerin çocuklarını en çok sağlık, güvenlik ve beslenme konularını öğrenmeleri için desteklediklerini belirlenmiştir. MANOVA sonuçları, okul öncesi ve ilkokul çocuklarının ailelerine kıyasla ortaokul çocuklarının ailelerinin doğa ve bilim etkinlikleri yapma boyutunda çocuklarını önemli ölçüde daha düşük düzeyde desteklediklerini ortaya koymuştur. Ayrıca, okul öncesi çocukları ile karşılaştırıldıklarında ortaokul çocuklarının madde, enerji ve canlılar ile ilgili fen konularını öğrenmeleri için aileleri tarafından daha düşük düzeyde desteklendikleri saptanmıştır. İlkokul ve ortaokul çocuğu olan ailelere kıyasla okul öncesi çocuğu olan ailelerin gökyüzü ile ilgili fen konularını öğrenmelerine yönelik çocuklarına daha çok fırsat sundukları tespit edilmiştir.

Anahtar Sözcükler: *Aile desteği, Fen öğrenme, Okul dışında fen*

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INTRODUCTION

All children, regardless of their future career fields, should construct a basic knowledge of science to involve in science-related public discussions, critically evaluate scientific information concerning their lives, and continue lifelong science learning (National Research Council, 2012). Conventionally, schools have been held accountable for teaching science; however, Korpan, Bisanz, Bisanz, Boehme, and Lynch (1997) question if schools are the main source for developing children's science literacy. Korpan et al. (1997) mainly argue that in communities where science instruction is confined to two hours in schools, children engage in a range of activities that helps them learn science outside schools such as watching television programs, reading books with their parents, participating in community-based programs, making observations, and doing experiments. Gelmez-Burakgazi and Yildirim (2014) also assert that children receive support from several informal sources such as internet, science magazines, and television to develop their science literacy. In a more recent study, Rosenthal (2018) shows that one third of the sample uses Youtube to watch science videos for learning science in their free times.

Informal science learning, basically defined as science learning outside traditional formal schooling, is based on the assumption that learning is not the product of a single experience but occurs over time through the accumulation of various experiences (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003). Maarschalk (1988) states that informal education, the education through the experiences in family and neighborhood, is both a condition and outcome for scientific literacy. Informal learning sources and experiences outside school can improve children's scientific reasoning abilities (Falk & Dierking, 2010; Gerber, Cavallo, & Marek, 2001; Şentürk, 2015), knowledge and understanding in science (Fenichel & Schweingruber, 2010), and motivation to learn science (Goto, Nakanishi, & Kano, 2018). As science instruction in classroom environments is mostly rigid and based on presentations, learning science through informal sources, which offers a more relaxing and friendly learning context (Jones, 1997; Kim & Dopico, 2016), can be more effective for some students. Thus, we must endeavor to blend formal experiences with informal experiences (Coll & Coll, 2018; Hofstein & Rosenfeld, 1996; Sun & Looi, 2018) for effective science education.

The current study addresses one of the significant informal science learning sources for children: Parents. Parents constitute one of the contexts where children can observe and understand nature (Eberbach & Crowley, 2017). Today, it is widely recognized that schools need the support of families to maximize children's benefits from schooling (Bronfenbrenner, 1994; Çelenk, 2003; Dabney, Chakrverty, & Tai, 2013; Desforges & Abouchaar, 2003; Epstein & Dauber, 1991; Gonzalez, Borders, Hines, Villalba, & Henderson, 2013; Keçeli-Kaysili, 2008). Parents can support the education of their children in different ways. For instance, "school-like families" primarily view their child as a student and care about their school activities for improving their child's achievement and skills (Epstein, 2010). Through creating a positive "academic home climate", as defined by Campbell and Verna (2007), parents can cultivate behaviors, attitudes, beliefs, and values that assist children in having higher levels of achievement. Parents can participate in school activities at school and as well support children's learning at home (Epstein & Dauber, 1991).

Regarding science education, parents can offer opportunities for their children to facilitate their learning of science topics outside school. They can facilitate their children's learning as they offer various science-related materials at home and engage in informal science activities with their children such as visiting science museums/zoos, participating in science camps/clubs, and being in nature (Lin & Schunn, 2016). Hall and Schaverien (2001) indicated that families' participation in children's scientific and technological inquiries at home had educational significance. Dierking and Falk (1994)

in their review study showed that family visits to informal science settings such as exhibits were vital for children's science education. Crowley and Callanan (1998) revealed that parents shaped children's scientific thinking during a museum visit as their interactions with children broadened and deepened their child's experience. De Lurdes Cardoso (2002) demonstrated that children were more actively involved and talked more freely in home-based science activities. Harris and Winterbottom (2018) observed that there was a relatively high level of conceptual and emotional talk between families and children during a gallery visit, and the families as the scaffolders facilitated their children's learning in these settings. In a more recent study, Vandermaas-Peeler, Mischka, and Sands (2019) noticed that parents were able to enhance their preschool children's science and mathematics learning and could support their children's reasoning better if the professionals encouraged and trained them regarding how to guide children's inquiry at home. Dou, Hazari, Dabney, Sonnert, and Sadler (2019), moreover, noted that talking about science with families and also friends during K-4 years was associated with individuals' seeing themselves as a STEM (science, technology, engineering, and mathematics) person in college. The above results clearly imply that parental support is one of the factors that warrants the attention of practitioners, educational researchers, and policy makers for improving children's science learning.

The Present Study

The current research seeks to investigate the parental support for children's science learning outside school. We pay attention to the three aspects of parental support in this paper: (a) the availability of basic science materials that can support children's science learning in their home environment, (b) the frequency of parents' involvement in informal science activities with their children, and (c) the level of opportunities parents offer their children for learning basic science subjects. Additionally, the study examines the parental support for children's science learning in three different grade levels including preschool, elementary school (Grades 1-4), and middle school (Grades 5-8) considering that children's age can predict parents' engagement in children's education (Oswald, Zaidi, Cheatham, & Brody, 2018).

This study is considered important mainly for three reasons. Firstly, children's science learning outside school constitutes an opportunity for effective science education; however, it has been investigated less in educational research compared to children's science learning at schools (Fraser & Kahle, 2007; Gerber, Marek, & Cavallo, 2001; Salmi, Thuneberg, & Vainikainen, 2017). To the best of our knowledge, there is a dearth of studies in literature on parental support regarding children's learning of science out of school contexts (e.g., Alexander, Johnson, & Kelley, 2012; Korpan et al., 1997; Renninger & Hidi, 2011). In his review study on informal science learning in the context of Turkey, Saraç (2017) as well demonstrates that the existing studies on informal learning environments in Turkey have been mostly carried out with middle school children and teachers, and have extensively focused on learning in museums, science centers, and field trips, whereas little is known regarding parental support for children's learning at home and outside home. The current study with its focus on parents as an informal learning source is likely to address a gap in the national literature. Secondly, this initial explorative research could contribute to the identification and discussion of needs regarding parental support for children's science learning. Results could offer implications for practitioners and policy makers for guiding parents to nurture the science learning of their children at different grade levels. Lastly, the study could inform researchers regarding the factors that need to be investigated in-depth in future research regarding parental support in science education.

METHODOLOGY

In this quantitative study, the cross-sectional survey method was applied to examine the opportunities parents offer their children of three different grade levels for science learning outside schools. In cross-sectional surveys, data are gathered one point in a time (Fraenkel, Wallen, & Hyun, 2012).

Sample

This study was conducted in a non-metropolitan city in the north region of Turkey. The sample involved the parents of preschool, elementary school and middle school children attending public schools. In Turkey, preschool education covers the education of children between the ages of 3 and 5. Elementary school children are between the ages of 6 and 10 and attend the grades between 1 and 4. The middle school level comprises the grades between 5 and 8 for children between the ages of 11 and 14. Cluster random sampling method was implemented in the selection of parents. In this sampling method, groups rather than individuals are selected because researchers do not have access to a complete list of the population (Fraenkel et al., 2012). In the selection of the sample, two steps were taken. In the first step, schools were selected to reach parents. As there are not many public pre-primary schools in the city, all pre-primary schools in the central districts (n = 3) were included in the sample. Moreover, six schools from the population of 14 public elementary schools and four schools from the population of 8 public middle schools were selected. Especially, the schools which included a higher number of students and located in urban and rural parts of the central area were involved in the sample. In the second step, two classes were randomly selected in the selected schools for each grade level. The survey forms were distributed to children in these classes to deliver them to their parents. In total, the forms were sent to 1392 parents in this study. Of these parents, 735 completed the survey form, corresponding to a response rate of 52.8%.

Table 1.
Characteristics of the sample (N = 735)

Variable	*n*	%
Respondent		
Mother	457	62.2
Father	243	33.1
Educational level of the respondent		
Elementary and below	149	20.3
Middle school	106	14.4
High school	181	24.6
Higher education	291	39.6
Perceived self-efficacy for answering children's questions about science		
No at all	30	4.1
Slightly	170	23.1
Moderately	415	56.5
Very	64	8.7
A great deal	40	5.4
Grade level of children		
Preschool education	99	13.5
Elementary school	395	53.7
Middle school	241	32.8

Table 1 displays the general characteristics of 735 parents involved in the current study. As shown in Table 1, 53.7% of the parents (n = 395) had elementary school children, 32.8% of the parents (n = 241) had middle school children, and 13.5% of the parents (n = 99) had preschool children. In the sample, the respondents were mostly the mothers of children (62.2%). The parents had various degrees of education in this study. Specifically, 39.6% had a higher education degree, whereas 20.3% had an

elementary education degree or below. More than half of the participants (56.5%) perceived themselves moderately efficacious to answer their children's questions about science.

Data Collection Tools

Data were collected through a parent questionnaire developed for the current study. The studies by Alexander et al. (2012), Olgan (2015), National Research Council (2012), and Saçkes (2014) guided the item development phase for the parent questionnaire. The questionnaire was reviewed by two science education experts, two curriculum specialists, and six parents with various educational degrees, and revised based on their feedback. The parent questionnaire is composed of the following three parts:

Science Materials at Home Questionnaire (SMHQ). SMHQ examines if specific 13 materials (e.g., magnifier, thermometer, and compass) that can support children's science learning are available in their home environment. The responses of the participants are received as Yes or No.

Parental Support for Informal Science Activities Questionnaire (PS-ISAQ). The PS-ISAQ intends to measure to what extent parents offer their children opportunities for involving in basic informal science activities based on a 5-point response scale (1: Never, 5: A great deal). This questionnaire addresses the parental support for thirteen informal science activities such as reading science-related books/ magazines, visiting a science museum, and making observation.

The PS-ISAQ was tested with 273 parents in a pilot study. The principal component analysis results showed that the scale was composed of three components, explaining 59.76% of the variance in the sample. The component loadings were all above the cut-off criteria of .32. The first component is *Using Sources*, which includes five items regarding the opportunities parents offer their children to use sources (e.g., book, video, experts) to learn science. The second component is *Making Science Trips*, which involves three items concerning the opportunities parents offer their children to participate in science trips. The third component, named as *Doing Science and Nature Activities*, is composed of five items and deals with the opportunities parents offer their children to engage in activities in which they actively do science and be in nature such as talking about science subjects, making observation, doing basic experiments, and participating in nature walk.

Confirmatory factor analysis (CFA) was performed to confirm the three-component structure for the PS-ISAQ for the sample used in this study. The CFA results indicated that the proposed model had a good fit to the data (Satorra-Bentler χ^2 (62) = 333.73, RMSEA = .08, CFI = .96, TLI = .95, SRMR = .06). The component loadings were all statistically significant. The items on each dimension were internally consistent. The Cronbach's alpha values were .80 for Using Sources, .73 for Making Science Trips, and .78 for Doing Science and Nature Activities.

Parental Support for Children's Learning of Science Subjects Questionnaire (PS-CLSSQ). The PS-CLSSQ aims to assess to what extent parents offer their children opportunities for learning basic science subjects based on a 5-point response scale (1: Never, 5: A great deal). The PS-CLSSQ inquiries into the parental support for seventeen science subjects such as motion, rock and soils, and seasons.

The PS-CLSSQ was subjected to the principal component analysis with a sample of 257 parents in the pilot study. The analysis revealed that two components best explained the structure of the PS-CLSSQ. In this model, the loadings of the seventeen items were all above the cut-off value of .32. The two-component model overall explained 59.84% of the variance in the sample. As the twelve items on the first component are about the opportunities parents offer their children to learn science subjects related matter, energy, and livings (e.g., rock and soil, heat and temperature, human body), this component is named as *Matter, Energy, and Livings*. The five items on the second component concern the

opportunities parents offer their children to learn science subjects related to sky (e.g., celestial objects, day and night) and thus this component is entitled as *Sky*.

The CFA was performed to test the two-component structure for the PS-CLSSQ in the current sample. The initial results indicated that the model needed improvement (Satorra-Bentler χ^2 (118) = 867.80, RMSEA = .10, CFI = .96, TLI = .96, SRMR = .06). Considering the modification indices and the content of items, the error covariances of the three pairs of items were set to be free in the model. These changes yielded an improved and acceptable model fit (Satorra-Bentler corrected χ^2 (115) = 589.41, RMSEA = .08, CFI = .98, TLI = .97, SRMR = .05). The factor loadings were all statistically significant. The Cronbach alpha values presented evidence for the internal consistency of the items on the two dimensions (.92 for Matter, Energy, and Livings; .89 for Sky).

Data Collection Process

The permissions were obtained from the Human Subjects Ethics Committee and the Provincial Directorate of National Education (Dated 07.02.2018 and No. 25072426-730.08.03-E.2583604) for data collection. We cooperated with the selected schools to contact with parents in the data collection process of the study.

Data Analysis

Data set was preliminarily screened for the incomplete values. The missing scores were less than 1% for each variable. As there were a few missing values, the multiple imputation with expectation-maximization algorithm was performed with the LISREL software. There was not any significant difference between the means obtained from the data set with missing values and those obtained from the data set with imputed values. As a result, the imputed data set was used in data analysis. The two questionnaires (i.e., PS-ISAQ and PS-CLSSQ) were subjected to the principal component analysis. Principal component analysis helps to reduce data to a manageable size (Field, 2009). The direct oblimin method was used for rotation because there was correlation among the components. The Kaiser-Meyer-Olkin value exceeded the recommended value of .70 (Field, 2009) for both PS-ISAQ and PS-CLSSQ. The component loadings were interpreted significant when they were .32 and greater (Tabachnick & Fidell, 2013). Confirmatory factor analyses (CFA) were also conducted for the PS-ISAQ and PS-CLSSQ with the LISREL software. The robust maximum likelihood method was selected in the estimation of parameters because multivariate normality was not met in the sample. The model fit was evaluated based on the multiple goodness-of-fit statistics. Specifically, a model is considered acceptable if RMSEA is .08 and less, TLI and CFI is .95 or greater, and SRMR is .10 or less (Schermelleh-Engel, Moosbrugger, & Müller, 2003).

Descriptive analysis and one-way multivariate analysis of variance (MANOVA) were performed to address the research questions in the present study. The inspection of normal Q-Q plots, histograms, as well as the skewness and kurtosis scores presented evidence regarding the normality of the distribution of scores in the sample. Mardia's test result showed a deviation of the multivariate normality in the data. However, this result was neglected because the violation of the multivariate normality assumption does not create severe problems with moderate sample sizes (Hair, Black, Babin, & Anderson, 2010). Two separate one-way MANOVAs were performed to examine the effect of children's grade level on the two aspects of parental support for children's science learning: parents' involvement in informal science activities with their children and the opportunities parents offer their children for learning basic science subjects. Each group should include at least 20 members for conducting MANOVA (Hair et al., 2010) and this condition was met in the current study. The Box's and Levene's tests evidenced that the assumptions of homogeneity of variance-covariance matrices and equality of variance were met. Bonferroni adjustment was applied in the interpretation of the tests of between-subjects effects to eliminate Type 1 error. The Scheffe post-hoc method was adopted to examine pairwise group differences because this method is considered appropriate for comparison when group sizes are not equal (Ruxton & Beauchamp, 2008).

RESULTS

The Availability of Basic Science Materials in Children's Home Environment

Table 2 presents the descriptive statistics regarding the existence of science materials that can support children's science learning in their home environment as reported by their parents.

Table 2.
Availability of science materials in children's home environment

Science material	Preschool		Elementary school		Middle school		Total group	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Magnifier	33	38.8	125	35.8	87	39.2	245	37.3
Microscope	7	8.2	14	4	5	2.3	26	4
Telescope	4	4.7	11	3.2	3	1.4	18	2.7
Binoculars	27	31.8	92	26.4	71	32	190	29
Compass	30	35.3	135	38.7	90	40.5	255	38.9
Thermometer	54	63.5	190	54.4	119	53.6	363	55.3
Toy Magnet	61	71.8	223	63.9	149	67.1	433	66
Toy electric circuits	19	22.4	78	22.3	76	34.2	173	26.4
Science-related printed materials (e.g., book, poster)	46	54.1	190	54.4	136	61.3	372	56.7
Model (e.g., earth model, human body model)	21	24.7	102	29.2	56	25.2	179	27.3
Science kits with basic experiments (e.g., electricity kit, botanic kit, chemistry kit)	13	15.3	45	12.9	47	21.2	105	16
Science-related computer applications (e.g., games, animations)	31	36.5	144	41.3	115	51.8	290	44.2
Collections of natural materials	39	45.9	134	38.4	87	39.2	260	39.6

The material preschool, elementary school and middle school children were most likely to have in their home environment was similarly toy magnets (71.8% for preschool, 63.9% for elementary school, 67.1% for middle school). More than 50% of the preschool, middle school and elementary school children had a thermometer (63.5% for preschool, 54.4% for elementary school, 53.6% for middle school) and science-related printed materials (54.1% for preschool, 54.4% for elementary school, 61.3% for middle school) at their home. More than half of the middle school children (51.8%) had access to science-related computer applications at home unlike preschool (36.5%) and elementary school (41.3%) children. The material preschool, elementary school and middle school children were least likely to have at their home was likewise telescope (4.7% for preschool, 3.2% for elementary school, 1.4% for middle school). Additionally, the parental reports indicated that more than 50% of the children across the three grade levels did not have a magnifier, binocular, compass, toy electric circuit, model, science kit, and collection of natural materials at their home.

The Frequency of Parents' Involvement in Informal Science Activities with Their Children

Table 3 presents the frequency of the parents' involvement in informal science activities with their children. The results revealed that children across the three grade levels were similarly least likely to have opportunities to involve in science trips with their parents. The mean values in this dimension were below 2 on the 5-point response scale for each grade level (M = 1.92, SD = 0.80 for preschool, M = 1.95, SD = 0.75 for elementary school, M = 1.91, SD = 0.82 for middle school). As regards parental support for children's use of sources to learn science, the mean scores were approaching to 3 in each grade level on the 5-point response scale (M = 2.75, SD = 0.79 for preschool, M = 2.77, SD = 0.81 for elementary school, M = 2.86, SD = 0.76 for middle school). In relation to the opportunities parents offer their children for doing science and nature activities, the mean value was close to 3 for the parents of middle school children (M = 2.78, SD = 0.85), while the average scores were slightly exceeding 3 for the parents of preschool and elementary school children (M = 3.21, SD = 0.70 for

preschool, *M* = 3.03, *SD* = 0.83 for elementary school). For the preschool and elementary school children, the level of parental support for children's doing science and nature activities was higher than the level of parental support for children's use sources to learn science. Yet the parents of middle school children seemed to offer their children slightly more opportunities to using sources than doing science and nature activities.

Table 3.
The frequency of the parents' involvement in informal science activities with their children

Informal science activity	Preschool		Elementary school		Middle school		Total group	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Using sources	2.75	0.79	2.77	0.81	2.86	0.76	2.80	0.79
Watching a science-related video/film	2.52	1.05	2.50	1.00	2.56	0.95	2.52	0.99
Reading science-related books / magazines	2.81	1.10	2.68	1.03	2.81	1.07	2.74	1.05
Watching science-related television programs	2.83	1.06	2.76	1.07	2.70	1.03	2.74	1.06
Doing science-related research on a question the child is curious about (book or internet search)	3.03	1.20	3.21	1.14	3.50	1.05	3.29	1.13
Consulting someone about science-related subjects	2.60	1.07	2.71	1.12	2.72	1.09	2.70	1.11
Making science trips	1.92	0.80	1.95	0.75	1.91	0.82	1.93	0.78
Visiting a science museum	1.71	0.94	1.71	0.90	1.76	0.98	1.73	0.93
Visiting a zoo / aquarium / botanical garden	2.48	1.10	2.55	1.07	2.28	1.13	2.45	1.10
Visiting a science fair / science festival	1.60	0.83	1.60	0.87	1.69	0.96	1.62	0.89
Doing science and nature activities	3.21	0.70	3.03	0.83	2.78	0.85	2.97	0.83
Talking with children about science subjects related to their daily lives	3.63	0.79	3.32	1.00	3.14	1.10	3.30	1.02
Making observations	3.33	0.92	3.12	1.09	2.81	1.13	3.05	1.10
Doing basic science experiments	2.76	0.97	2.61	1.13	2.59	1.15	2.62	1.11
Participating in nature walk	2.73	1.23	2.65	1.19	2.40	1.23	2.58	1.21
Collecting various materials from nature	3.58	1.05	3.44	1.20	2.98	1.28	3.30	1.23

Considering thirteen informal science activities examined in the current study, the lowest mean score was obtained for visiting a science fair/festival across the three grade levels (*M* = 1.60, *SD* = 0.83 for preschool, *M* = 1.60, *SD* = 0.87 for elementary school, *M* = 1.69, *SD* = 0.96 for middle school, *M* = 1.62, *SD* = 0.89 for total group). However, the activity parents offered their children most frequently varied by grade level. For the preschool group, the activity with the highest mean score was talking with children about science subjects which are part of their daily lives (*M* = 3.63, *SD* = 0.79). For the group of elementary school, parents reported that they offered their children the highest level of support for collecting various materials from nature (*M* = 3.44, *SD* = 1.20). On the other side, the parents of the middle school children supported their child most in doing research about a question their child was curious about (*M* = 3.50, *SD* = 1.05).

The Level of Opportunities Parents Offer Their Children for Learning Basic Science Subjects

Table 4 displays the level of opportunities parents offer their children to learn basic science subjects related to two dimensions: matter-energy-livings and sky. The total group mean scores for both dimensions were nearly 3 on the 5-point response scale (*M* = 3.02, *SD* = 0.83 for subjects related to matter, energy, and livings, *M* = 2.96, *SD* = 0.96 for subjects related to sky). As regards the level of opportunities parents offered their children to learn subjects related to matter, energy, and livings, the mean score was slightly exceeding 3 for the parents of preschool (*M* = 3.25, *SD* = 0.76) and elementary school children (*M* = 3.02, *SD* = 0.81) on the 5-point response scale. The mean score of this dimension was slightly less than 3 for the middle school group (*M* = 2.91, *SD* = 0.87). The level of opportunities parents offered their preschool children to learn subjects related to sky was on average above 3 on the 5-point response scale (*M* = 3.30, *SD* = 0.91). Yet for the elementary and middle school grade levels, the mean value for the parental support for children's learning of subjects related to sky was slightly below 3 on the 5-point response scale (*M* = 2.95, *SD* = 0.96 for elementary school, *M* = 2.83, *SD* = 0.96 for middle school). The means for both dimensions were higher for preschool group compared to the elementary and middle school groups.

Table 4.
The level of opportunities parents offer their children for learning basic science subjects

Science subject	Preschool		Elementary school		Middle school		Total group	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Matter-Energy-Livings	3.25	0.76	3.02	0.81	2.91	0.87	3.02	0.83
Properties of matters in nature	2.98	1.08	2.99	1.10	2.89	1.16	2.95	1.11
Motion	3.42	1.03	3.19	1.14	3.02	1.21	3.16	1.15
Light and shadow	3.20	0.95	2.77	1.05	2.65	1.13	2.78	1.08
Sound	3.28	1.02	2.94	1.10	2.87	1.24	2.96	1.14
Heat and temperature	3.04	1.10	2.89	1.07	2.91	1.12	2.92	1.09
Electricity	2.67	1.14	2.57	1.16	2.65	1.16	2.61	1.15
Magnets	2.78	1.06	2.70	1.14	2.70	1.26	2.71	1.17
Plants and animals	3.58	0.98	3.32	1.15	3.20	1.16	3.31	1.13
Human body	3.39	1.02	3.09	1.15	2.83	1.21	3.04	1.17
Health, security, nutrition	3.89	0.91	3.58	1.07	3.48	1.10	3.59	1.96
Rock and soil	3.31	1.18	3.09	1.18	2.67	1.25	2.98	1.22
Water	3.48	1.06	3.19	1.21	3.05	1.29	3.19	1.23
Sky	3.30	0.91	2.95	0.96	2.83	0.96	2.96	0.96
Celestial objects (sun, moon, stars)	3.28	1.10	2.81	1.25	2.63	1.22	2.81	1.23
Solar system and space	2.92	1.14	2.45	1.24	2.47	1.19	2.52	1.22
Day and night	3.30	1.05	2.88	1.18	2.75	1.24	2.89	1.20
Seasons	3.44	1.01	3.23	1.06	3.05	1.21	3.20	1.12
Weather condition	3.53	1.03	3.37	1.06	3.25	1.23	3.35	1.12

Considering seventeen basic science subjects specified in the present study, preschool, elementary and middle school children were similarly supported most by their parents in the area of health, security, and nutrition (M = 3.89, SD = 0.91 for preschool, M = 3.58, SD = 1.07 for elementary school; M = 3.48, SD = 1.10 for middle school; M = 3.59, SD = 1.96 for total group). Plants and animals, and weather condition were the two subjects that were supported more compared other basic subjects in each grade level. The science subject for which parents offered their children least opportunity for learning was electricity in the preschool group (M = 2.67, SD = 1.14), while the science subject parents were least likely to support was solar system and space for elementary (M = 2.45, SD = 1.24) and middle school groups (M = 2.47, SD = 1.19).

The Effect of the Grade Level on Parental Support for Children's Science Learning

The first MANOVA results indicated that there was a significant effect of children's grade level on the linear combination of the three dependent variables regarding the frequency of the parents' involvement in informal science activities with their children: F (6, 1404) = 2737.65, p = .000; Wilks' Lambda = .93. The partial eta squared result showed that the grade level explained 4% of the variance in the sample. When the effect of the grade level for the three dependent variables was examined separately, the results demonstrated that the grade level significantly influenced the level of opportunities parents offered their children for doing science and nature activities (F (2, 704) = 10.999, p = .000, partial eta squared = .03). Yet the grade level did not have any significant effect on the level of the opportunities parents offered their children for using sources to learn science and making science trips. The multiple comparisons with the Scheffe post hoc method showed a significant difference between the parents of preschool and middle school children and between the parents of elementary and middle school children. The parents of the middle school children offered significantly less opportunities for their children to do science and nature activities compared to the parents of preschool and elementary school children.

The second MANOVA results indicated that the grade level of children significantly influenced the combined dependent variables related to the extent of the opportunities parents offered their children for learning basic science subjects: F (4, 1340) = 3.952, p = .003; Wilks' Lambda = .98. Given the partial eta squared result, the grade level explained 1% of the variance in the sample. The effect of the

grade level was significant for both dependent variables: F (2, 671) = 5.434, p = .005, partial eta squared = .02 for parental support for science subjects related to matter, energy, and livings; F (2, 671) = 7.518, p = .001, partial eta squared = .02 for parental support for science subjects related to sky. The multiple comparisons with the Scheffe post hoc procedure showed that there was a significant difference between the parents of the preschool and middle school children regarding the level of opportunities they offered their children to learn basic science subjects related to matter, energy, and livings. Moreover, the parents of preschool children were significantly different from the parents of elementary and middle school children regarding the level of opportunities they offered their children to learn basic science subjects related to sky. The results demonstrated that the parents of preschool children offered significantly more opportunities for their children to learn science subjects related to matter, energy, and livings than the parents of middle school children. In addition, parental support for learning science subjects related to sky was significantly higher for preschool children compared to elementary and middle school children.

DISCUSSION

The present study attempted to examine the informal science learning opportunities parents offered their preschool, elementary school and middle school children in the context of Turkey. The study presents four main findings that warrant discussion.

First, results indicated that most children across the three grade levels (i.e., preschool, elementary school, middle school) had limited access to a range of materials that could support their science learning in their home environment. Telescope and microscope, emerged as the two materials unavailable in most of children's home, might not be affordable for most parents. On the other hand, it should be noted that some cheap materials which can be easily supplied by parents such as a magnifier, binocular, compass, and natural materials were not also present in majority of the homes in the study. The inexistence of various science materials in children's home environments is viewed as a limitation for children's science learning given that the materials at home play an important role in stimulating children for engaging in informal scientific inquiries (Sha, Schunn, Bathgate, & Ben-Eliyahu, 2016; Worth, 2010).

Second, this study revealed that parents did not often provide their children with opportunities to involve in informal science activities despite the existing evidence regarding parental contributions to children's learning during informal science activities (e.g., Crowley & Callanan, 1998; De Lurdes Cardoso, 2002; Halim, Abd Rahman, Zamri, & Mohtar, 2018; Harris & Winterbottom, 2018; Vandermaas-Peeler et al., 2019). Several informal science activities that parents could perform in everyday life with their children (e.g., reading science books, watching science videos/films, talking with children about science subjects, making observations) occurred roughly at a moderate level in the present sample. This result aligns with previous research showing that parental support at home for children's learning occurred at a medium level in Turkey (e.g. Aksu & Karaçöp, 2015; Çağdaş, Özel, & Konca, 2016). Importantly, the current results highlighted that most children regardless of their grade level were not involved in science trips by their parents. This finding might be because there is not currently a science museum, zoo, or any other science area to visit in the city where this study was conducted. In addition, it is worthy to mention that science fairs/festivals are often organized as school events which do not require parental involvement in the city.

Third, the level of opportunities parents offered their children to learn basic science subjects was overall moderate in the present study. The study indicated that parents offered their children more learning opportunities for specific science subjects. Considering the subjects supported most in each grade level (i.e., health, security, and nutrition, plants and animals, and weather condition), it can be

argued that the parents assisted their children more for learning science subjects that exerted a direct influence on their daily lives. In addition, parents might be more likely to support their children' learning for science subjects that they perceive to be easy to understand. It seems that the science subjects supported less by the parents in the current study (e.g., electricity, solar system and space) demand an advanced level of scientific understanding. It must be noted that the parents' level of self-efficacy for answering children's science-related questions was mostly moderate or below in the current sample. As stated by Lee and Nie (2015), the low self-efficacy for science can hinder parents from involving in their children's science education. Thus, it becomes critical that parents improve their own scientific understanding and efficacy to help their children learn basic science subjects.

Fourth and finally, there was evidence that the grade level significantly influenced the parental support for children's science learning outside school. The parents of middle school children did not support their children to do science and nature activities as much as the parents of preschool and elementary school children. Moreover, the preschool children obtained more support from their parents for learning science topics than the elementary and middle school children. These findings are likely to support that parent involvement in children's education decreases as child age increases (e.g., Green, Walker, Hoover-Dempsey, & Sandler, 2007; Hornby & Lafaele, 2011; Oswald et al., 2018). The lower levels of parental support in upper grades might be because of children's desire for greater independence as they get older (Green et al., 2007) as well as the lack of strong, positive, and comprehensive parent involvement programs for middle school grades (Epstein & Dauber, 1991). Additionally, children's age might alter how parents engage in their children's education (Hurley, Lambert, January, & D'Angelo, 2017). Boonk, Gijselaers, Ritzen, and Brand-Gruwel (2018) in their review study conclude that parent involvement does not decrease by children's age but occurs in different ways. Considering their argument, the current results might not necessarily show that the parents of the middle school children are less interested in involving in children's science learning. They might support the science learning of their children outside schools in ways which are not examined in the current study.

CONCLUSION

The present findings are likely to support the argument that the value of parent involvement in education has not been recognized yet in the context of Turkey (Keçeli-Kaysili, 2008; Özeke-Kocabaş, 2006) although involving parents in education has been a significant component of Turkish Education System especially since the education reform movement that took place in 2005 based on a constructivist way of teaching (Koc, Isiksal, & Bulut, 2007). The low level of parental support for children's science learning outside school in Turkey might be because some Turkish parents (a) hold schools accountable for the education of their children, (b) are not conscious about how to involve in the education of their children, and (c) are not supported by teachers and school administrators to involve in educational processes (Erdoğan & Demirkasımoğlu, 2010). Some Turkish parents might as well think that parent involvement is not necessary because they think that their child is already learning effectively and is a middle school student (Kasapoğlu, 2014).

If parents do not effectively support their children's science learning outside school, children's science education will be mostly restricted to formal school experiences. The current science education curriculum of Turkey also highlights the significance of science learning out of school environments (Ministry of National Education, 2018). To improve parental support for children's science learning outside school, parents' beliefs about their role in the education of their children, their sense of efficacy for supporting their children's learning, and their beliefs about the opinions of the child and school about their involvement need to be addressed (Hoover-Dempsey & Sandler, 1997; Walker, Wilkins, Dallaire, Sandler, & Hoover-Dempsey, 2005). We should awaken parents regarding the

importance of their involvement in children's learning of science through informal ways (Lee & Nie, 2015). For this end, teachers and schools should guide parents about what to do at home (Epstein, 1986; Hamlin & Flessa, 2018; Leithwood & Patrician, 2015), and establish well-designed programs of family and community partnerships (Epstein & Salinas, 2004). These programs should especially help parents improve their perception of capabilities for supporting children's science learning and increase their interest in involving in their children's education (Kaya & Lundeen, 2010). In these programs, it is also important to show parents that science is not necessarily a laboratory discipline that requires elaborate equipment but part of everyday life (Fleer, 1996).

Limitations and Suggestions for Future Research

This study has several limitations. For the external validity, it is important to replicate the current study with samples drawn from different regions of Turkey. The use of self-report data is a significant threat to the internal validity of the study. In this study, it is acknowledged that parents provide sincere responses rather than socially desirable answers. The triangulation of data sources could improve the validity of results; thus, future studies should examine how children and teachers evaluate parental support for science learning outside school. In the present study, the influence of the grade level on parental support for children's science learning was statistically significant but it is worthy to mention that this effect was not considered large based on Cohen's criteria (1988) (i.e., small = .01, medium = .06, large = .14). Future qualitative studies might help to identify the factors that exert a greater influence on parental support for children's science learning across different grades. There is also a need for cross-cultural research to scrutinize the cultural differences in how parents support the education of their children. Moreover, longitudinal studies should be conducted to examine how parental support for children's science learning changes as children grow. Future research should also shed light into the quality of learning opportunities for children because the outcomes of science learning outside school depend on the quality of parental support as well as its frequency. In this regard, we recommend that scholars pay attention to the quality of parent-child interactions during science learning experiences outside school. The current study addressed to what extent parents supported their children to learn basic science subjects rather than the means parents used for supporting their children's learning of different science topics. Therefore, it may be important to reveal how parents support their children's learning of various science topics in future research.

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REFERENCES

Aksu, F. F., & Karaçöp, A. (2015). Ev temelli fen öğrenme etkinliklerine aile katılımının bazı değişkenler açısından incelenmesi [An investigation of the parental involvement in home-based science learning activities in terms of some variables]. *Bayburt Eğitim Fakültesi Dergisi, 10*(1), 154-179.

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education, 96*(5), 763-786. DOI: 10.1002/sce.21018

Boonk, L., Gijselaers, H. J. M., Ritzen, H., & Brand-Gruwel, S. (2018). A review of the relationship between parental involvement indicators and academic achievement. *Educational Research Review, 24*, 10-30. DOI: 10.1016/j.edurev.2018.02.001

Bronfenbrenner, U. (1994). *Ecological models of human development.* Retrieved from http://www.psy.cmu.edu/~siegler/35bronfebrenner94.pdf

Campbell, J. R., & Verna, M. A. (2007). Effective parental influence: Academic home climate linked to children's achievement. *Educational Research and Evaluation, 13*(6), 501-519. DOI: 10.1080/13803610701785949

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Coll, S. D., & Coll, R. K. (2018). Using blended learning and out-of-school visits: pedagogies for effective science teaching in the twenty-first century. *Research in Science and Technological Education*, *36*(2), 185-204. DOI: 10.1080/02635143.2017.1393658

Crowley, K., & Callanan, M. (1998). Describing and supporting collaborative scientific thinking in parent-child interactions. *Journal of Museum Education, 23*(1), 12–17. DOI: 10.1080/10598650.1998.11510365

Çağdaş, A., Özel, E., & Konca, A. S. (2016). İlkokul başlangıcında velilerin aile katılım düzeylerinin incelenmesi [Investigating parental involvement at beginning of elementary school]. *Journal of Theory and Practice in Education, 12*(4), 891-908.

Çelenk, S. (2003). Okul başarısının ön koşulu: Okul aile dayanışması [The Prerequisite for school success: Home-school cooperation]. *İlköğretim Online, 2*(2), 28-34.

Dabney, K. P., Chakraverty, D., & Tai, R. H. (2013). The association of family influence and initial interest in science. *Science Education, 97*(3), 395-409. DOI: 10.1002/sce.21060

De Lurdes Cardoso, M. (2002). Studies of Portuguese and British primary pupils learning science through simple activities in the home. *International Journal of Science Education, 24*(1), 47-60. DOI: 10.1080/09500690110049079

Desforges, C., & Abouchaar, A. (2003). *The impact of parental involvement, parental support and family education on pupil achievement and adjustment: A literature review.* (Research Report No. RR433). Retrieved from https://www.nationalnumeracy.org.uk/sites/default/files/the_impact_ of _parental_involvement.pdf

Dierking, L. D., & Falk, J. H. (1994). Family behavior and learning in informal science settings: A review of the research. *Science Education, 78*(1), 57-72. DOI: 10.1002/sce.3730780104

Dierking, L. D., Falk, J. H., Rennie, L., Anderson, D., & Ellenbogen, K. (2003). Policy statement of the "informal science education" ad hoc committee. *Journal of Research in Science Teaching, 40*(2), 108-111. DOI: 10.1002/tea.10066

Dou, R., Hazari, Z., Dabney, K., Sonnert, G., & Sadler, P. (2019). Early informal STEM experiences and STEM identity: The importance of talking science. *Science Education, 103*(3), 623-637. DOI: 10.1002/sce.21499

Eberbach, C., & Crowley, K. (2017). From seeing to observing: How parents and children learn to see science in a botanical garden. *Journal of the Learning Sciences, 26*(4), 608-642. DOI: 10.1080/10508406.2017.1308867

Epstein, J. L. (1986). Parents' reactions to teacher practices of parent involvement. *The Elementary School Journal, 86*(3), 277-294. DOI: 10.1086/461449

Epstein, J. L. (2010). School/family/community partnerships: Caring for the children we share. *Phi Delta Kappan, 92*(3), 81-96. DOI: 10.1177/003172171009200326

Epstein, J. L., & Dauber, S. L. (1991). School programs and teacher practices of parent involvement in inner-city elementary and middle schools. *The Elementary School Journal, 91*(3), 289-305. DOI: 10.1086/461656

Epstein, J. L., & Salinas, K. C. (2004). Partnering with families and communities. *Educational Leadership, 61*(8), 12-19.

Erdoğan, Ç., & Demirkasımoğlu, N. (2010). Ailelerin eğitim sürecine katılımına ilişkin öğretmen ve yönetici görüşleri [Teachers' and school administrators' views of parent involvement in education process]. *Kuram ve Uygulamada Eğitim Yönetimi Dergisi*, *16*(3), 399-431.

Falk, J. H., & Dierking, L. D. (2010). The 95 percent solution. *American Scientist, 98*(6), 486-493.

Fenichel, M., & Schweingruber, H. A. (2010). *Surrounded by science: Learning science in informal environments.* Washington, DC: The National Research Council of National Academies Press.

Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). London: Sage.

Fleer, M. (1996). Fusing the boundaries between home and child care to support children's scientific learning. *Research in Science Education, 26*(2), 143-154. DOI: 10.1007/BF02356428

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). New York: McGraw-Hill Education.

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home and peer environment influences on student outcomes in science and mathematics: An analysis of systemic reform data. *International Journal of Science Education, 29*(15), 1891-1909. DOI: 10.1080/09500690601167178

Gelmez-Burakgazi, S., & Yildirim, A. (2014). Accessing science through media: Uses and gratifications among fourth and fifth graders for science learning. *Science Communication, 36*(2), 168-193. DOI: 10.1177/1075547013505847

Gerber, B. L., Cavallo, A. M., & Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education, 23*(5), 535-549. DOI: 10.1080/09500690116971

Gerber, B. L., Marek, E. A., & Cavallo, A. M. (2001). Development of an informal learning opportunities assay. *International Journal of Science Education, 23*(6), 569-583. DOI: 10.1080/09500690116959

Gonzalez, L. M., Borders, L. D., Hines, E. M., Villalba, J. A., & Henderson, A. (2013). Parental involvement in children's education: Considerations for school counselors working with Latino immigrant families. *Professional School Counseling, 16*(3), 185-193. DOI: 10.1177/2156759X1701600303

Goto, T., Nakanishi, K., & Kano, K. (2018). A large-scale longitudinal survey of participation in scientific events with a focus on students' learning motivation for science: Antecedents and consequences. *Learning and Individual Differences, 61*, 181-187. DOI: 10.1016/j.lindif.2017.12.005

Green, C. L., Walker, J. M., Hoover-Dempsey, K. V., & Sandler, H. M. (2007). Parents' motivations for involvement in children's education: An empirical test of a theoretical model of parental involvement. *Journal of Educational Psychology, 99*(3), 532-544. DOI: 10.1037/0022-0663.99.3.532

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Upper Saddle River, NJ: Prentice Hall.

Halim, L., Abd Rahman, N., Zamri, R., & Mohtar, L. (2018). The roles of parents in cultivating children's interest towards science learning and careers. *Kasetsart Journal of Social Sciences, 39*(2), 190-196. DOI: 10.1016/j.kjss.2017.05.001

Hall, R. L., & Schaverien, L. (2001). Families' engagement with young children's science and technology learning at home. *Science Education, 85*(4), 454-481. DOI: 10.1002/sce.1018

Hamlin, D., & Flessa, J. (2018). Parental involvement initiatives: An analysis. *Educational Policy, 32*(5), 697-727. DOI: 10.1177/0895904816673739

Harris, E., & Winterbottom, M. (2018). 'Why do parrots talk?' co-investigation as a model for promoting family learning through conversation in a natural history gallery. *Journal of Biological Education, 52*(1), 89-100. DOI: 10.1080/00219266.2017.1408934

Hoover-Dempsey, K. V., & Sandler, H. M. (1997). Why do parents become involved in their children's education? *Review of Educational Research, 67*(1), 3-42. DOI: 10.3102/00346543067001003

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education, 28*(1), 87-112. DOI: 10.1080/03057269608560085

Hornby, G., & Lafaele, R. (2011). Barriers to parental involvement in education: An explanatory model. *Educational Review, 63*(1), 37-52. DOI: 10.1080/00131911.2010.488049

Hurley, K. D., Lambert, M. C., January, S. A. A., & D'Angelo, J. H. (2017). Confirmatory factor analyses comparing parental involvement frameworks with secondary students. *Psychology in the Schools, 54*(9), 947-964. DOI: 10.1002/pits.22039

Jones, L. S. (1997). Opening doors with informal science: Exposure and access for our underserved students. *Science Education, 81*(6), 663-677.

Kasapoğlu, K. (2014). *Facilitators and distractors of effective learning: Perceptions of middle school students, teachers and parents* (Unpublished doctoral dissertation). Middle East Technical University, Ankara, Turkey.

Kaya, S., & Lundeen, C. (2010). Capturing parents' individual and institutional interest toward involvement in science education. *Journal of Science Teacher Education, 21*(7), 825-841. DOI: 10.1007/s10972-009-9173-4

Keçeli-Kaysili, B. (2008). Akademik başarının arttırılmasında aile katılımı [Parent involvement to improve academic achievement]. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Özel Eğitim Dergisi, 9*(1), 69-83.

Kim, M., & Dopico, E. (2016). Science education through informal education. *Cultural Studies of Science Education, 11*(2), 439-445. DOI: 10.1007/s11422-014-9639-3

Koc, Y., Isiksal, M., & Bulut, S. (2007). Elementary school curriculum reform in Turkey. *International Education Journal, 8*(1), 30-39.

Korpan, C. A., Bisanz, G. L., Bisanz, J., Boehme, C., & Lynch, M. A. (1997). What did you learn outside of school today? Using structured interviews to document home and community activities related to science and technology. *Science Education, 81*(6), 651-662.

Lee, A. N., & Nie, Y. (2015). The 'Why'and 'How'of engaging parents in their children's science learning in informal contexts: Theoretical perspectives and applications. In M. S. Khine (Ed.), *Science Education in East Asia* (pp. 93-121). Switzerland: Springer.

Leithwood, K., & Patrician, P. (2015). Changing the educational culture of the home to increase student success at school. *Societies, 5*(3), 664-685. DOI: 10.3390/soc5030664

Lin, P. Y., & Schunn, C. D. (2016). The dimensions and impact of informal science learning experiences on middle schoolers' attitudes and abilities in science. *International Journal of Science Education, 38*(17), 2551-2572. DOI: 10.1080/09500693.2016.1251631

Maarschalk, J. (1988). Scientific literacy and informal science teaching. *Journal of Research in Science Teaching*, *25*(2), 135-146. DOI: 10.1002/tea.3660250205

Ministry of National Education (2018). *Fen Bilimleri dersi öğretim programı* [Science education curriculum]. Retrieved from file:///C:/Users/Casper/Downloads/201812312311937FEN%20B%C4%B0L%C4%B0MLER%C4%B0%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI2018.pdf

National Research Council (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, D.C, USA: The National Academies Press.

Olgan, R. (2015). Influences on Turkish early childhood teachers' science teaching practices and the science content covered in the early years. *Early Child Development and Care, 185*(6), 926-942. DOI: 10.1080/03004430.2014.967689

Oswald, D. P., Zaidi, H. B., Cheatham, D. S., & Brody, K. G. D. (2018). Correlates of parent involvement in students' learning: Examination of a national data set. *Journal of Child and Family Studies, 27*(1), 316-323. DOI: 10.1007/s10826-017-0876-4

Özeke-Kocabaş, E. (2006). Eğitim sürecinde aile katılımı: Dünyada ve Türkiye'deki çalışmalar [Parent involvement in education: Studies in Turkey and in the world]. *Türk Psikolojik Danışma ve Rehberlik Dergisi*, *3*(26), 143-153.

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist*, *46*(3), 168-184. DOI: 10.1080/00461520.2011.587723

Rosenthal, S. (2018). Motivations to seek science videos on YouTube: free-choice learning in a connected society. *International Journal of Science Education*, *8*(1), 22-39. DOI: 10.1080/21548455.2017.1371357

Ruxton, G. D., & Beauchamp, G. (2008). Time for some a priori thinking about post hoc testing. *Behavioral Ecology*, *19*(3), 690-693. DOI: 10.1093/beheco/arn020

Saçkes, M. (2014). How often do early childhood teachers teach science concepts? Determinants of the frequency of science teaching in kindergarten. *European Early Childhood Education Research Journal, 22*(2), 169-184. DOI: 10.1080/1350293X.2012.704305

Salmi, H., Thuneberg, H., & Vainikainen, M. P. (2017). Making the invisible observable by Augmented Reality in informal science education context. *International Journal of Science Education, Part B*, *7*(3), 253-268. DOI: 10.1080/21548455.2016.1254358

Saraç, H. (2017). Türkiye'de okul dışı öğrenme ortamlarına ilişkin yapılan araştırmalar: İçerik analizi çalışması [Researches related to outdoor learning environments in Turkey: Content analysis study]. *Eğitim Kuram ve Uygulama Araştırmaları Dergisi*, *3*(2), 60-81.

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, *8*(2), 23-74.

Sha, L., Schunn, C., Bathgate, M., & Ben-Eliyahu, A. (2016). Families support their children's success in science learning by influencing interest and self-efficacy. *Journal of Research in Science Teaching*, *53*(3), 450-472. DOI: 10.1002/tea.21251

Sun, D., & Looi, C-K. (2018). Boundary interaction: Towards developing a mobile technology- enabled science curriculum to integrate learning in the informal spaces. *British Journal of Educational Technology*, *49*(3), 505-515. DOI: 10.1111/bjet.12555

Şentürk, E. (2015). *Field trips to science centers: Teachers' perspectives, roles, and reflections* (Unpublished doctoral dissertation). Middle East Technical University, Ankara, Turkey.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson.

Vandermaas-Peeler, M., Mischka, M., & Sands, K. (2019). "What do you notice?" Parent guidance of preschoolers' inquiry in activities at home. *Early Child Development and Care*, *189*(2), 220-232. DOI: 10.1080/03004430.2017.1310724

Walker, J. M., Wilkins, A. S., Dallaire, J. R., Sandler, H. M., & Hoover-Dempsey, K. V. (2005). Parental involvement: Model revision through scale development. *The Elementary School Journal*, *106*(2), 85-104. DOI: 10.1086/499193

Worth, K. (2010). *Science in early childhood classrooms: Content and process*. Retrieved from http://ecrp.uiuc.edu/ beyond/seed/worth.html.

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Okullar geleneksel olarak çocukların fen öğrenmelerinden sorumlu görülse de fen öğrenme süreci sadece okullarda gerçekleşmemektedir. Korpan, Bisanz, Bisanz, Boehme ve Lynch (1997) televizyon izleme, aile ile kitap okuma, toplum temelli programlara katılma, gözlemleme ve deney yapma gibi çeşitli okul dışı etkinliklerin çocukların fen öğrenmelerine yardımcı olduğuna dikkat çekmiştir. Gelmez-Burakgazi ve Yıldırım (2014) da Türkiye örnekleminde çocukların fen öğrenmek için internet, bilimsel dergiler ve televizyon gibi informal kaynaklardan destek aldıklarını göstermiştir. Alanyazın, çocukların okul dışında gerçekleşen informal fen etkinliklerinden daha çok keyif aldıklarını (Fenichel ve Schweingruber, 2010) ve informal fen etkinliklerinin çocukların fen öğrenme motivasyonunu arttırdığını (Goto, Nakanishi ve Kano, 2018) göstermektedir.

Bu çalışma, çocuklar için önemli informal fen öğrenme kaynaklarından birisine odaklanmaktadır: Aileler. Özellikle, bu araştırmada ailelerin okul dışında fen öğrenme için çocuklarına sağladıkları destek ele alınmıştır. Zira çocuklar, ailelerinin desteği ile doğayı gözlemleyebilir ve anlayabilirler (Eberbach ve Crowley, 2017). Bu çalışmada çocukların fen öğrenmesine yönelik aile desteği üç boyutta incelenmiştir: (a) çocukların fen öğrenmesini destekleyebilecek temel fen materyallerine ev ortamlarında erişim durumu, (b) ailelerin çocukları ile birlikte informal fen etkinliklerine katılım düzeyi ve (c) ailelerin çocuklarına temel fen konularını öğrenmelerine yönelik sundukları fırsatların düzeyi. Önemli bir husus olarak, çocukların yaşının aile katılımı üzerindeki etkisi (Oswald, Zaidi, Cheatham ve Brody, 2018) göz önünde bulundurularak, okul öncesi, ilkokul (1.-4. sınıf) ve ortaokul (5.-8. sınıf) olmak üzere üç öğretim düzeyinde ailelerin çocuklarına fen öğrenmeleri için sundukları destek düzeyinde bir fark olup olmadığı araştırılmıştır. Bu çalışmanın üç temel nedenden dolayı önemli olduğu düşünülmektedir. Birincisi, etkili fen eğitimi için okul dışında öğrenme kritik bir öneme sahip olmasına rağmen eğitim araştırmalarında daha çok çocukların okul ortamında fen öğrenmelerine odaklanılmıştır (Gerber, Marek ve Cavallo, 2001; Fraser ve Kahle, 2007; Salmi, Thuneberg ve Vainikainen, 2017). Alanyazında çocukların okul dışında fen öğrenmelerine ilişkin aile desteği konusunda az sayıda çalışmaya rastlanılmaktadır (örneğin, Alexander, Johnson ve Kelley, 2012; Korpan ve diğerleri, 1997; Renninger ve Hidi, 2011). İkincisi, bu araştırma çocukların fen öğrenme sürecinde ailelerin sağladığı desteğe ilişkin ihtiyaçları ortaya koymaya katkı sağlayacaktır. Bu ihtiyaçların bilinmesi ile çocuklarının fen öğrenmelerini okul dışında desteklemeleri hususunda ailelere daha etkili rehberlik sağlanabilir. Son olarak, bu öncü nicel araştırma fen eğitimde aile desteğine ilişkin daha kapsamlı incelenmesi gereken faktörlere yönelik sonraki araştırmalara yol gösterebilir.

Bu çalışmada kesitsel tarama modeline başvurulmuştur. Veriler, Türkiye'nin kuzey bölgesindeki bir ilden toplanmıştır. Çalışmaya bu ilin merkez ilçelerindeki devlet okullarına devam eden okul öncesi, ilkokul (1.- 4. sınıf) ve ortaokul (5.- 8. sınıf) çocukları olan aileler dahil edilmiştir. Örneklem seçimi iki aşamada gerçekleştirilmiştir. İlk aşamada ailelere ulaşmak için okullar seçilmiştir. İkinci aşamada, seçilen okullarda her bir sınıf seviyesi için rastgele iki şube belirlenmiş ve bu şubelerdeki çocuklara ailelerine ulaştırmak üzere anket formları dağıtılmıştır. Bu çalışmada toplam 1392 aileye anket gönderilmiştir. Cevaplama oranı %52,8'e karşılık gelerek, bu ailelerden 735'i anket formunu doldurmuştur. Araştırmaya katılan 735 ailenin %53,7'sinin (n = 395) ilkokulda, %32,8'nin (n = 241) ortaokulda ve %13,5'inin (n = 99) okul öncesinde öğrenim görmekte olan çocuğu bulunmaktadır. Örneklemde katılımcıların çoğunluğunu anneler oluşturmaktadır (%62,2). Katılımcıların %39,6'sı bir yükseköğretim kurumundan mezun iken, %20,3'ü ilkokul mezunu ya da ilkokul kademesinin altında bir eğitim düzeyine sahiptir. Veriler ilgili alanyazın incelenerek araştırmacılar tarafından geliştirilen aile anketi aracılığıyla toplanmıştır. Anket maddelerinin geliştirilmesinde Alexander ve arkadaşlarının (2012), Olgan'ın (2015), Ulusal Araştırma Konseyi'nin (National Research Council, 2012) ve Saçkes'in (2014) çalışmalarından yararlanılmıştır. Anket iki fen eğitimi uzmanı, iki eğitim programı

uzmanı ve çeşitli eğitim derecesine sahip altı aile tarafından gözden geçirilmiş ve iletilen geri bildirimler ışığında yeniden düzenlenmiştir. Aile anketi, ev ortamında bulunan fen materyalleri, ailelerin çocukları ile birlikte informal fen etkinliklerine katılım düzeyleri ve ailelerin temel fen konularına ilişkin olarak çocuklarına öğrenme fırsatı sunma düzeyleri olmak üzere üç bölümden oluşmaktadır. Anket için geçerlik ve güvenirlik kanıtları bulunmaktadır. Araştırma sorularına cevap vermek amacıyla betimleyici istatistiklere ve tek yönlü çok değişkenli varyans analizine (MANOVA) başvurulmuştur.

Oyuncak mıknatıslar okul öncesi, ilkokul ve ortaokul çocuklarının ev ortamlarında benzer şekilde en yüksek oranda bulunan materyal olarak ortaya çıkmıştır (Okul öncesi için %71,8, İlkokul için %63,9, Ortaokul için %67,1). Okul öncesi, ilkokul ve ortaokul çocuklarının %50'sinden fazlasının evinde termometre (Okul öncesi için %63,5, İlkokul için %54,4, Ortaokul için %53,6) ve bilim ile ilgili basılı materyaller (Okul öncesi için %54,1, İlkokul için %54,4, Ortaokul için %61,3) bulunduğu saptanmıştır. Okul öncesi (%36,5) ve ilkokul (%41,3) çocuklarının aksine, ortaokul çocuklarının yarısından fazlasının (%51,8) bilim ile ilgili bilgisayar uygulamalarına evlerinde erişebildiği bulunmuştur. Teleskop, okul öncesi, ilkokul ve ortaokul çocuklarının evlerinde en düşük oranda bulunan materyal olarak tespit edilmiştir (Okul öncesi için %4,7, İlkokul için %3,2, Ortaokul için %1,4). Ayrıca, aile raporlarına göre üç öğretim düzeyinde de çocukların %50'sinden fazlasının evinde büyüteç, dürbün, pusula, oyuncak elektrik devresi, model/maket, bilim kitleri ve doğal materyal koleksiyonunun bulunmadığı ortaya çıkmıştır.

Üç öğretim düzeyinde de benzer şekilde ailelerin bilim gezilerine katılma boyutunda çocuklarını en düşük düzeyde destekledikleri ortaya çıkmıştır. Bu boyut için ortalama değerler her bir öğretim seviyesi için 5'lik cevaplama kategorisinde 2'nin altında bulunmuştur (Okul öncesi için *Ort.* = 1.92, *SS* = 0.80, İlkokul için *Ort.* = 1.95, *SS* = 0.75, Ortaokul için *Ort.* = 1.91, *SS* = 0.82). Fen öğrenmek için kaynak kullanımına yönelik aile desteği boyutuna ilişkin ortalamalar her üç öğretim seviyesinde 5'lik cevaplama kategorisinde 3'e yakın bulunmuştur (Okul öncesi için *Ort.* = 2.75, *SS*= 0.79, İlkokul için *Ort.* = 2.77, *SS* = 0.81, Ortaokul için *Ort.* = 2.86, *SS* = 0.76). Çocukların fen ve doğa etkinlikleri yapmasına yönelik aile desteğine ilişkin olarak, ortaokul çocuklarının ailelerinin ortalama değeri 3'e yakın bulunurken (*Ort.* = 2.78, *SS* = 0.85), bu boyuta ait ortalama değerlerin okul öncesi ve ilkokul çocuklarının aileleri için 3'ü biraz geçtiği tespit edilmiştir (Okul öncesi için *Ort.*= 3.21, *SS* = 0.70, İlkokul için *Ort.* = 3.03, *SS* = 0.83). Okul öncesi ve ilkokul çocukları için fen ve doğa etkinlikleri yapma boyutuna ilişkin aile desteği, fen öğrenmek için kaynak kullanımı boyutuna ilişkin aile desteğinden daha yüksek bulunmuştur. Ancak ortaokul çocuklarının ailelerinin, fen ve doğa etkinlikleri yapmaya kıyasla fen öğrenimi için kaynakları kullanmaya yönelik olarak çocuklarına daha fazla fırsat sundukları belirlenmiştir.

İlk MANOVA sonuçları, ailelerin çocuklarına informal fen etkinliklerine katılmaya yönelik sundukları fırsatlarla ilgili üç bağımlı değişkenin doğrusal kombinasyonu üzerinde öğretim seviyesinin önemli bir etkisinin olduğunu göstermiştir: F (6, 1404) = 2737.65, p = .000; Wilks' Lambda =.93. Kısmi eta kare değeri, öğretim seviyesi tarafından örneklemde açıklanan varyansın %4 olduğunu ortaya koymuştur. Üç bağımlı değişken için sonuçlar ayrı ayrı incelendiğinde, bulgular öğretim seviyesinin ailelerin fen ve doğa etkinlikleri yapmak için çocuklarına sundukları fırsatların düzeyini önemli bir şekilde etkilediğini göstermiştir (F (2, 704) = 10.999, p = .000, kısmi eta kare değeri = .03). Scheffe post hoc testi yöntemiyle ortaokul çocuklarının ailelerinin okul öncesi ve ilkokul çocuklarının ailelerine kıyasla fen ve doğa etkinlikleri yapma boyutunda çocuklarına önemli ölçüde daha düşük düzeyde destek oldukları tespit edilmiştir. İkinci MANOVA sonuçları, öğretim seviyesinin ailelerin temel fen konularını öğrenmelerine yönelik çocuklarına sundukları fırsatlarla ilgili iki bağımlı değişkenin kombinasyonunu önemli ölçüde etkilediğini göstermiştir (F (4, 1340) = 3.952, p = .003; Wilks' Lambda = .98). Kısmi eta kare değerine göre öğretim seviyesi örneklemdeki varyansın %1'ini açıklamıştır. Öğretim seviyesinin her iki bağımlı değişken üzerindeki etkisinin önemli olduğu bulunmuştur: Madde, enerji ve canlılar ile ilgili konular için F (2, 671) = 5.434, p = .005, kısmi eta kare değeri = .02; Gökyüzü ile ilgili konular için F(2, 671) = 7.518, p = .001, kısmi eta kare değeri = .02. Scheffe post hoc yöntemi ile yapılan çoklu karşılaştırmalar, okul öncesi çocuklarının ailelerinin

ortaokul çocuklarının ailelerine kıyasla madde, enerji ve canlılar ile ilgili fen konularını öğrenmelerine yönelik çocuklarına önemli ölçüde daha fazla fırsat sunduklarını göstermiştir. Ayrıca, okul öncesi dönemdeki çocuklara gökyüzü ile ilgili fen konularını öğrenmelerine yönelik sunulan aile desteği, ilkokul ve ortaokul çocuklarına sağlanan aile desteğinden anlamlı düzeyde daha yüksek bulunmuştur.

Bu bulgular okul dışında çocukların fen öğrenmeleri hususunda aile desteğinin geliştirilmesine yönelik bir ihtiyaç olduğunu göstermektedir. Özellikle ortaokul çocuklarının informal fen eğitiminde aile desteği daha yakından incelenmelidir. Çocuklarının eğitimindeki rollerine ilişkin aile inançları, çocuklarına yardımcı olma konusundaki aile öz yeterlik algısı ve hem çocuğun hem okulun aile katılımına ilişkin görüşlerine yönelik aile inançları ailelerin çocuklarının eğitimine katılım konusundaki kararlarını etkileyebilmektedir (Hoover-Dempsey ve Sandler, 1997; Walker, Wilkins, Dallaire, Sandler ve Hoover-Dempsey, 2005). Özellikle Türkiye'de eğitimde aile katılımının düşük seviyede olması (a) ailelerin çocuklarının eğitiminden öncelikle okulları sorumlu tutmaları, (b) ailelerin çocuklarının eğitimine nasıl katılacakları konusunda bilinçli olmamaları ve (c) öğretmenlerin ve okul yöneticilerinin eğitim sürecine ailelerin katılımını sağlamak için fazla çaba göstermemeleri ile açıklanabilir (Erdoğan ve Demirkasımoğlu, 2010). Ayrıca Türkiye'de aileler, çocuklarının zaten etkili bir şekilde öğrendiklerini düşündükleri ve çocukları ortaokulda öğrenim gördüğü için aile katılımını gerekli görmüyor olabilirler (Kasapoğlu, 2014). Çocukların okul dışı öğrenme fırsatlarından yoksun kalmamaları için öncelikli olarak bu konuda aile farkındalığı geliştirilmelidir (Lee ve Nie, 2015). Bu amaç doğrultusunda, öğretmenler ve okullar, aileleri evde neler yapabilecekleri hakkında yönlendirmeliler (Epstein, 1986; Leithwood ve Patrician, 2015) ve iyi tasarlanmış aile ve toplum iş birliği programları oluşturmalılardır (Epstein ve Salinas, 2004). Bu programlar özellikle ailelerin çocuklarının fen öğrenmelerini desteklemeye yönelik yeterlik algılarının gelişmesine yardımcı olmalı ve ailelerin çocuklarının eğitimine katılmaya yönelik ilgisini artırmalıdır (Kaya ve Lundeen, 2010). Bu programlarda aynı zamanda Fen Bilimlerinin mutlaka özel araç-gereç gerektiren bir laboratuvar disiplini olmadığına ve aslında günlük yaşamın bir parçası olduğuna dikkat çekilmelidir (Fleer, 1996).

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Developing biomimicry STEM activity by querying the relationship between structure and function in organisms

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ABSTRACT The theme that structure determines function is one of the most significant cornerstones in understanding natural sciences. On the other hand, recently revised science curriculum in Turkey has emphasized science and engineering practices to help students be able to converge science with the other disciplines by applying theory into practice and product; but there is not an emphasis on the repeating patterns and relationships between structure and function for natural and built systems at any grades. In order to close this gap, the main objective of this study is to develop an integrated biomimicry STEM activity about the unit of Living Things World at grade five. This paper reported on a case study of 21 fifth-grade students' gaining experiences about the engineering design process by mimicking a structure from the organisms to solve a human problem. Even more striking result is that students can manage to incorporate biomimicry into their design solutions by the way of complementary relationship between structure and function in organisms.

Keywords: *Biomimicry, Design, Function, STEM Education, Structure*

Organizmalarda bulunan yapı fonksiyon ilişkisi sorgulanarak biyomimikri STEM etkinliği geliştirilmesi

ÖZ Doğa bilimlerini anlamada en önemli mihenk taşlarından biri yapı fonksiyonu belirler temasıdır. Diğer taraftan Türkiye'de yakın zamanda revize edilen fen programında ise öğrencilerin feni diğer disiplinlerle bütünleştirerek teoriyi pratiğe ve ürüne dönüştürebilmelerine yardımcı olacak fen ve mühendislik uygulamalarına vurgu yapılırken; doğada ya da tasarlanmış dünyada tekrar eden örüntülere ve yapı ve işlev arasındaki ilişkilere herhangi bir sınıf düzeyinde vurgu yapılmamıştır. Bu açığı kapatmak için çalışmada, beşinci sınıf fen bilimleri dersi Canlılar Dünyası ünitesinde yapı ve fonksiyon ilişkisine dayanan bütünleştirilmiş biyomimikri STEM etkinliği geliştirmek amaçlanmıştır. Bu çalışma, 21 beşinci sınıf öğrencisinin insanlığa ait bir problemi çözmek için organizmalara ait bir yapıyı taklit ederek mühendislik tasarım süreci ile ilgili deneyimlerini aktaran bir durum çalışmasıdır. Çalışmanın çarpıcı bir sonucu ise, öğrencilerin organizmalardaki yapı ve fonksiyon arasındaki tamamlayıcı ilişki yoluyla biyomimikriyi tasarım çözümlerine dahil etmeyi başarabilmeleridir.

Anahtar Sözcükler: *Biyomimikri, Fonksiyon, STEM Eğitimi, Tasarım, Yapı*

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INTRODUCTION

The understanding of the relationship between structure and function has been recognized both as a crosscutting and disciplinary core concepts in the current reform document of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Framework)* (National Research Council [NRC], 2012). Amongst the seven crosscutting concepts as unifying themes across all the disciplines and grade levels, structure and function are defined as "the way in which an object or living thing is shaped and its substructure determine many of its properties and functions" (NRC, 2012, p. 84). The theme that structure determines function is one of the most significant cornerstones in understanding natural sciences. Structure is the way that an organism is shaped as a whole. Functions are the processes that help an organism to survive. The structure and function of an organism work complementarily in nature to meet the needs of the organism. Understanding these causal relationships between structure and function through the identification of mechanisms like behaviors in life sciences can be delineated by Structure–Behavior–Function (SBF) theory. The SBF theory makes it explicit how structure and function causally related with a bridge of behaviors/actions (Hmelo, Holton, & Kolodner, 2000; Hmelo-Silver, Marathe, & Liu, 2007). In this way, the SBF theory may account for coherent science learning in providing students to understand the purposes and processes of the structures to achieve their function (Hmelo-Silver et al., 2008). Also, when biological function is used in the same meaning as adaptation, it may account for understanding the origin of a structure's function that emerged in the evolutionary process (Kohn, Underwood, & Cooper, 2018).

As related to the extent in which students understand the functions of structures by querying organisms or molecules in the natural world requires making causal inferences. This is a similar way by which "engineers make such inferences when examining structures in nature as inspirations for designs to meet people's needs" (Next Generation Science Standards [NGSS] Lead States, 2013b, p.89). Engineers learn from studying nature; so they observe nature to get brilliant ideas for design solutions to solve human problems. This explains why technological tools we use in our daily life usually work in the same way as something in nature. As it can be seen that "the functioning of natural and built systems alike depends on the shapes and relationships of certain key parts as well as on the properties of the materials from which they are made" (NRC, 2012, p.96). Such scientific explanations of the relation between structure and function in natural systems can be further delineated by mimicking the translation of these observations into design solutions to solve human problems for STEM (Science, Technology, Engineering, and Mathematics) education. Therefore, understanding the purpose or mechanical function of structures in nature as a learning outcome in science courses should be considered in STEM education.

STEM education proposes an interdisciplinary integration of knowledge, skill, and beliefs relate to more than one STEM disciplines through the collaborative efforts of students and teachers (Çorlu, Capraro, & Capraro, 2014; Öner et al., 2014). To accomplish this goal, engineering and engineering design process-oriented integration for science teaching has been appreciated in the current reform documents (e.g., NRC, 2012) and related literature (e.g., Guzey, Thank, Wang, Roehrig, & Moore, 2014; Moore et al., 2014). Amongst the scope of Integrated Teaching Framework (ITP), which is considered as an effort for the pedagogical interpretation of STEM for Turkish context, the methodological integration means to use both the discipline and the methods of a particular field education in the teaching of other fields depending on the interests of teachers and students. The four main principles of integrated STEM education are defined as equity, relevance, interdisciplinarity and rigor (Aşık, Doğança Küçük, Helvacı & Çorlu, 2017). In parallel to this pedagogy as proposed by Aşık et al., (2017), the current study is an example for the use of the engineering design process or engineering-based learning in science classes.

Structure and Function as a Crosscutting and Core Concept

The *Framework* (NRC, 2012) defines crosscutting concepts as to "bridge disciplinary boundaries, having explanatory value throughout much of science and engineering" (p. 83). These concepts provide students useful lenses for recognizing similarities among disciplinary core ideas and practices in science and engineering. Thus, crosscutting concepts are common themes emerging across all science and engineering disciplines to help students better understand phenomena. As the NGSS document points out, there is no need to teach and assess these concepts as a separate vocabulary from practices or disciplinary context. Rather, the crosscutting concepts should be embedded in the science curriculum from beginning in the early grades of schooling and growing in complexity and sophistication across the grades (NGSS Lead States, 2013b).

The relationship between structure and function as a crosscutting concept can sometimes be essential to make causal inferences as a special case of cause and effect (NGSS Lead States, 2013b). Table 1 indicates that exploration of the relationship between structure and function should begin in the early grades and progress in complexity across the grades both as crosscutting and disciplinary core concepts. In early grades students can relate the shape and stability of structures for a variety of functions like a bridge's diagonal brace or mechanical function such as wheels, axles, and gears. As students' progress through the upper grades they are expected to improve from recognizing particular structures or substructures observed in the visible systems to a more complex, small scale, non- visible systems are related to their functions (NRC, 2012).

Table 1.
Progression of ideas for the structure and function both as a crosscutting concept and disciplinary core idea (Adapted from Duschl, 2012; NGSS Lead States, 2013b)

Grades	Structure and function as a crosscutting concept	Structure and function as a core idea in the life sciences
K-2	Examine relationships of structure and function in accessible and visible natural and human built systems.	All organisms have external parts that they use to perform daily functions.
3-5	Matter has a substructure that is related to properties of materials. Begin study of more complex systems by examining subsystems and the relationships of the parts to their functions.	Organisms have both internal and external macroscopic structures that allow for growth, survival, behavior, and reproduction.
6-8	Visualize, model, and apply understandings of structure and function to more complex and less easily observable systems and processes. The concept of matter having submicroscopic structures is related to properties of matter.	All living things are made up of cells. In organisms, cells work together to form tissues and organs that are specialized for particular body functions.
9-12	Apply the knowledge of structure and function when investigating unfamiliar phenomena; when building something or deciphering how a system works, begin with examining what it is made of and what shapes its parts take.	Systems of specialized cells within organisms help perform essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors.

In this respect, understanding the structure and function as a topic for the life sciences should be emphasized as well. Bybee (2013) states the main goal of biology as to "develop explanations for functions based on structures and reciprocal-to explain the complementarity of structures and functions among an organism's systems and subsystems" (p.26). Likewise, the life sciences (LS) in the *Framework* focus on patterns, processes, and relationships of living organisms. The first core idea 'LS1: From molecules to organisms: Structures and processes' addresses the characteristic structures of organisms to live, grow, respond to their environment, and reproduce. As the first subcomponent 'LS1.A: Structure and function' explains how the structures of organisms enable life's functions by beginning from cells as the basic structural units to structural systems and subsystems of organisms that perform specialized functions (NRC, 2012). As it can be seen in Table 1, students at elementary grades are expected to investigate the relationships between the external and internal structures of organisms and their functions in growth, survival, behavior, and reproduction at the macroscale systems. Students in middle grades are expected to investigate explanations for the structure and function of cells as the basic units of life at microscale systems. Students at higher levels demonstrate

an understanding of how systems of cells function together to support the life processes, the hierarchical systems of organisms, and the role of specialized cells for maintenance and growth.

Why Teach Biomimicry?

The term biomimicry originates from Greek roots bios that means life and mimicry that means to imitate. Beyond its simple meaning of imitation of life, biomimicry is defined as "a creative form of technology that uses or imitates nature to improve human lives" (Hwang et al., 2015, p.5701). The origin of the term coined as biomimetics, bionics, bio-inspired design that are all used usually in the same meaning in the scientific literature. It has been considered as a new discipline of science starting from the book of Janine Benyus's in 1997 titled "Biomimicry: Innovation Inspired by Nature". In her book, biomimicry is defined as "a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems e.g., a solar cell inspired by a leaf" (Benyus, 2002, p.0). In other words, biomimicry as an approach "seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies" (Biomimicry Institute, 2010). According to Benyus (2002) billions of years of evolutionary process have given living organisms an amazing diversity of structures, shapes and their related functions to survive. Thus, learning from studying nature for perfection, accuracy and sustainability of natural mechanisms is the underlying philosophy of Benyus's theory of biomimicry.

There are well known examples of biomimicry in the history of human industrialization like Leonardo da Vinci's (1452–1519) work designed a "flying machine" by mimicking a bird and Wright brothers' (1867–1948) airplane designed by mimicking the wings of eagles. Nowadays, transportation vehicles may become faster, more stable, and more aerodynamic but still nature gives inspiration like Japanese bullet train mimicking a kingfisher's beak to reduce sonic boom and air resistance. It can be seen that biomimetic technology is applied in many different fields including material science, robotics, nanotechnology, product, design, innovation, inventions, systems design, architecture, agriculture, chemistry, medicine, communication and mechanics. One of the best known product examples of biomimicry is Velcro, a common hook-and-loop fastener, invented in 1948 by Swiss engineer George de Mestral who inspired from the fruit of the burr that sticks to his clothes and his dog's fur while hiking (Hwang et al., 2015; Pauw, Kandachar, Karana, Peck, & Wever, 2010).

There are three levels to mimic a natural system as regard to the increasing complexity from the organism level, to behavior level and ecosystem level. Biomimicry at the organism level indicates the mimicry of a specified organism or a part from the whole organism. Biomimicry at the behavior level indicates the mimicry of behavior in a specified organism. Biomimicry at the ecosystem level indicates the mimicry of whole ecosystem. At each level biomimicry can take place as a form about how it looks, material about what it is made from, construction about how it is made, process about how it works, and function about what is the capability. For example, building that mimics termites in architecture is a good representative of three levels and their sub-dimensions. At the organism level the building looks like a termite. At the behavior level the building looks like such a termite mound that is made by termites. At the ecosystem level the building looks like an ecosystem such termites would live in (Aziz & El sherif, 2016).

While learning from studying nature there are two main approaches suggested for a biomimicry design process as indicated in Figure 1. Top-down approach or challenge to biology begins with an identified human need or problem and then looks intentionally into nature how organisms or ecosystems solve this problem for better design solutions. Conversely, bottom-up approach or biology to design begins by examining nature to identify a particular structure, behavior or function belongs to an organism or ecosystem for transmitting this bio-inspired design solution into a human problem (Aziz & El sherif, 2016).

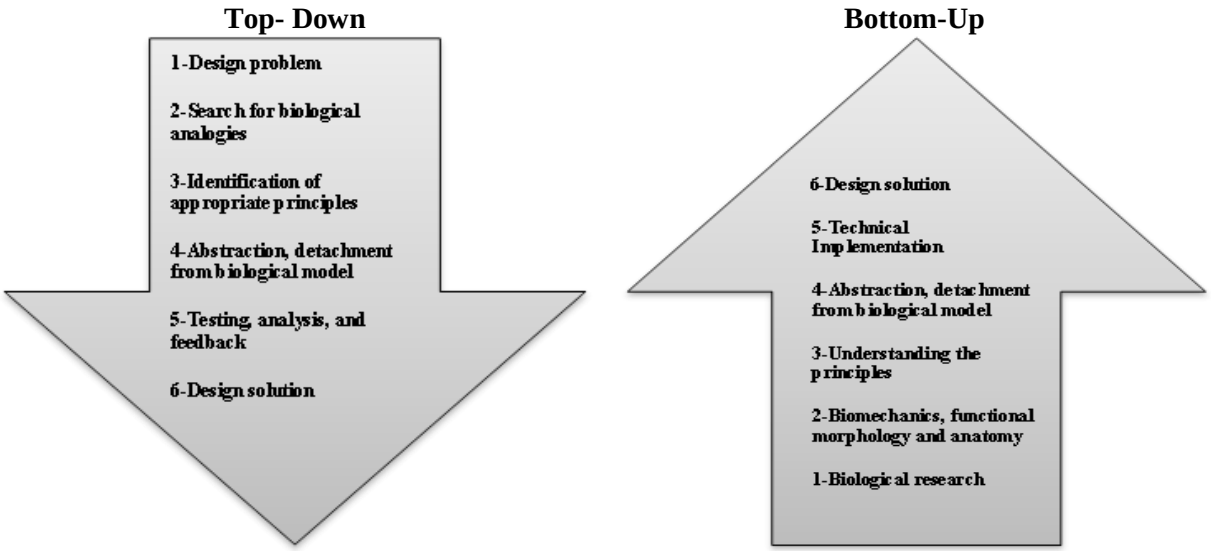

Figure1. Biomimicry top-down and bottom-up approaches (Adapted from Aziz & El sherif, 2016)

It is inevitable that using nature as a model for sustainable design solutions has initiated the conceptualization of biomimicry in science education. Biomimicry can be viewed as a revolution in education by offering teachers a way to inspire students of all ages by blending life sciences, STEM, creative problem solving, design, and systems thinking (Biomimicry Institute, 2010). Teaching biomimicry in STEM education can provide a context by intersecting nature with science, technology, engineering and math. Consequently, being inspired by nature requires understanding how nature works by identifying various functional and environmental adaptation mechanisms of organisms and their sustainability in basic science courses at early stages.

Rationale for the Study

As proposed in the *Framework* when the students develop an understanding about the relationships between structure and function, they can apply this knowledge to learn an unfamiliar scientific phenomenon and solve how a system work as a critical element of successful engineering designs (NRC, 2012). Similarly, recently revised science curriculum in Turkey has emphasized science and engineering practices to help students be able to converge science with the other disciplines by applying theory into practice and product; but there is not an emphasis on the repeating patterns and the relationships between structure and function for natural and built systems at any grades (Ministry of National Education [MoNE], 2018). On the other hand, students are expected to classify living things according to their similarities and differences as microscopic organisms, fungi, plants, and animals within the context of the unit of Living Things World at grade five. In order to close this gap in science education, the main objective of this study is to develop integrated biomimicry STEM activity based on the relationship between structure and function in organisms both as an engineering design principle and core component of life sciences for fifth graders to achieve learning outcomes about the classification of living things. In the line with this main aim, the research questions are: (a) How students develop a deep understanding of structure and function about living things? (b) How students develop a deep understanding about the role of biomimicry in engineering design principles?

For this purpose the performance expectations related to the topic of structure and function in the life sciences from the NGSS were adapted to develop biomimicry STEM activity. NGSS Lead States (2013a) emphasizes biomimicry as a performance expectation linked to the structure and function as one of the main component ideas in the life sciences of the first grade numbered as 1-LS1-1 and fourth grade numbered as 4-LS1-1 as indicated in Figure 2. The Figure 2 displays examples of performance expectations for elementary school life sciences with supporting content from the foundation box which combines practices, core ideas and crosscutting concepts.

PERFORMANCE EXPECTATIONS

Students who demonstrate understanding can:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. *[Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin.] [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.]*

1-LS1-1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.* *[Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and, detecting intruders by mimicking eyes and ears.]*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). (4-LS1-1) Construct an argument with evidence, data, and/or a model. Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information. Read grade-appropriate texts and use media to obtain scientific information to determine patterns in and/or evidence about the natural world. (4-LS1-1) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions. Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (4-LS1-1) Use materials to design a device that solves a specific problem or a solution to a specific problem. (1-LS1-1)	LS1.A: Structure and Function Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1) LS1.A: Structure and Function All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (1-LS1-1) LS1.D: Information Processing Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive. Plants also respond to some external inputs. (1-LS1-1) ETS1.A: Defining and Delimiting an Engineering Problem Asking questions, making observations, and gathering information are helpful in thinking about problems. (1-LS1-1) ETS1.B: Developing Possible Solutions Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (1-LS1-1) ETS1.C: Optimizing the Design Solution Because there is always more than one possible solution to a problem, it is useful to compare and test designs. (1-LS1-1)	Patterns Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (4-LS1-1) Structure and Function The shape and stability of structures of natural and designed objects are related to their function(s). (1-LS1-1) Systems and System Models A system can be described in terms of its components and their interactions. (4-LS1-1) - *Connections to Engineering, Technology, and Applications of Science* Influence of Science, Engineering and Technology on Society and the Natural World Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world. (1-LS1-1) - *Connections to Nature of Science* Scientific Knowledge is Based on Empirical Evidence Scientists look for patterns and order when making observations about the world. (4-LS1-1) Science is a human endeavor Science affects everyday life. (1-LS1-1) Most scientist and engineers work in teams. (1-LS1-1)

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

Figure 2. The performance expectations for LS1: From molecules to organisms: Structures and processes (Adapted from NGSS Lead States, 2013a)

METHODOLOGY

This study employed a case study in which "the researcher develops an in depth analysis of a case, often a program, event, activity, process, or one or more individuals" (Creswell, 2014, p.13). The case involves students' learning experiences by participating in the biomimicry STEM activity about organisms. The participants of the study were 10-11 years old 21 students (11 boys, 10 girls) attending 5th grade at the public lower secondary school in Antalya, Turkey. According to Yıldırım and Şimşek (2016), "if the researcher wants to introduce a new application or a novelty, he/she can identify them by determining one or more of the most typical among a series of case in which this application has been done or has innovativeness (p.120). For this purpose, the study group was determined in line with the typical case sampling which is one of the methods of purposeful sampling (Yıldırım & Şimşek, 2016) that emerged within the qualitative research tradition.

Biomimicry STEM activity worksheets, reflective open-ended questions, semi-structured interviews, rubrics were utilized in collecting data to evaluate the performances of the students and the effectiveness of the STEM activity. The data collection tools focused on obtaining the data in order to reveal how students develop a deep understanding of structure and function about living things and the role of biomimicry in engineering design principles. Students' learning experiences, difficulties which were experienced and how they overcame these difficulties, likes and dislikes, what they learned and how they worked in a team were investigated.

The qualitative collected throughout students' reflections about the engineering design process on open-ended questions and semi structured interviews, teacher's observations and field notes and participant students' portfolios were evaluated by descriptive analysis. The participant teacher's observations and field notes were used to increase the verification by guiding students' learning and behavior in the process. The abbreviations T for team, S for student and numbers were used to introduce the student's team and the student member such that T4.S1 means 4th team 1st student.

Ethical Approval

The typical case sampling aims to describe and illustrate what is typical to those unfamiliar with the setting, not to make generalized statements about the experiences of all participants (Patton, 2014). Prior to the implementation of the research, the necessary permission was obtained according to board decision, dated 05/02/2019 and 2439445 numbered, from the Research Evaluation and Investigation Committee of the Antalya National Education Directorate. Written informed parental consent forms including options of opt-out and opt-in for their children's participation in the research and collecting data from them were sent home to signature. The students were volunteer and had the signed parental consent forms involved in the study.

Description of Biomimicry STEM Activity

Biomimicry STEM activity provides students the learning opportunity to explore the relationship between structure and function in organisms both as an engineering design principle and a core component of life sciences for 5th graders in the unit of Living Things World. For this study some parts especially involving structure and function activities are described here in detailed. The activity consists of four main parts for science and engineering practices in parallel to the science standards as described below:

Part 1 – Asking Questions and Defining Problems. A scenario about biomimicry design task is given students (see Appendix 1) to introduce a problem or need for the engineering design task. After completing the next stages students consider how a human problem can be solved by mimicking a

structure from the organisms that has similar purpose for the engineering design process. Students then identify a human problem and develop their own design solutions inspired by organisms' adaptations.

Part 2 – Engaging in Argument from Evidence. It is expected that students get to know different kinds of organisms, determine the structures belonging to these organisms and explain how these structures help them to continue their lives by utilizing scientific resources or throughout their individual investigations. Using the scientific popular books like published by Scientific and Technological Research Council of Turkey (TUBITAK) titled "First Reading Series: Bees, Elephants, Spiders, Penguins, Bears, Owls, Caterpillars and Butterflies, Dogs, Trees etc." would help students develop an understanding of how particular features help animals and plants to survive. Students then complete the worksheet of Structure and Function as individually given in Appendix 2 to keep the observed structures and their functions in different organisms from different resources. Teachers' use of science talk along within these texts can promote students to obtain scientific information in examining structures and inferring their functions. To reinforce and extend this understanding as a core idea of life sciences teachers can have students engage in constructing arguments that plants and animals have internal and external structures functioning to support survival, growth, behavior, and reproduction with evidence, data, and/or a model. Similarly, as a crosscutting concept of structure and function at this stage it is explicitly emphasized that "the structure or shape of an object or system is frequently related to use, operation, or function. Scientists infer function by referring to form and also explain form by referring to function" (Lederman, 2019).

Part 3 – Obtaining, evaluating, and communicating information. Designing Imaginary Organism activity is given students to enhance the understanding the organisms' adaptations in relation to structure and function. It is expected that students get to design their own imaginary organism within their groups by using the previously gathered data from the observation of organisms' particular structure and their function. They decide structures and their functions that the organisms need to survive by describing their adaptations on the worksheet of Imaginary Organism's Adaptations given in Appendix 3. After they identify their imaginary organisms' structures, feeding type, predators, habitat, physical and behavioral adaptations etc., they draw their imaginary organism on the worksheet of Drawing and Labelling the Imaginary Organism given in Appendix 4 by describing the traits and adaptations on it. By using the worksheet of Introducing Imaginary Organism given in Appendix 5 groups decide the scientific name and other characteristics to classify their organisms. They can also write a story or news about the investigation of their imaginary organism in the given part of Appendix 4. In order to introduce their organism for the rest of the class, groups make the model of their imaginary organism by depicting on one of their friends by using provided materials in the classroom. During the presentation of the model organisms of the groups, students would be asked to present what functions their organisms have and why they interpret particular structures in that way. Another way of presenting the model organisms would be audience students asked to infer what the function might be from the structure of organisms. Students can also be asked why they used particular materials for the structure that they infer. At this moment, it is an appropriate time to discuss the distinction between observation and inference. The structure would directly be observable using our senses, but its function is not directly observable (Lederman, 2019). During the presentations, the teacher evaluates the model organisms that each group has by using the Imaginary Organism Assessment Rubric (see Appendix 6).

Part 4 – Constructing Explanations and Designing Solutions. Students are introduced with the great design task through a scenario given at first that defines biomimicry and how bioengineers inspire nature to develop new ideas for innovations. Using the scientific knowledge and models learned in the previous steps in which students make such observations about animals and plants' adaptations for survival, growth and meeting their needs, they can translate this information in a larger study to design a solution to a human need. In reverse relation, students would be asked to give examples by identifying and comparing designed objects related to natural shapes and structures. This investigation provides students to connect how observations of the natural world aid human survival. Then, they are asked to identify a human problem to develop a possible solution by using biomimicry which may be

an imitation of the relation between structure and function that belongs to organisms. As bioengineers students draw their prototype design solutions and describe how their design solutions solve the human problem on the worksheet of Great Design Task Draft Drawing given in Appendix 7. After deciding on the best design solution, students are supplied with materials to design a prototype model that solves a specific problem or a solution to a specific problem. In the last step students test, evaluate and analyze their design solutions within their groups to improve their model. Once the process is completed, groups present their biomimicry models in respect to the relations between the design and inspirations from the natural world by providing an analysis of the design process. During the presentations, the teacher evaluates the biomimicry models that each group has by using the Biomimicry Design Task Assessment Rubric (see Appendix 8).

Implication Steps of Biomimicry STEM Activity

Biomimicry STEM activity was planned to cover all the outcomes about the classification of living things within a larger dissertation study based on engineering design based unit phases (Wendell et al., 2010) and eight step engineering design process of Massachusetts Department of Education (2006). The study was conducted for twelve hours during the science lessons at the first term of the school year of 2018-2019 by the second author of this research. The activity was started with the identification of the need or the problem. During the two-lesson hour, students identified the human need or problem which was given in the scenario. They described the criteria and constraints. After identification of the needs/problem, they were researching the need/ problem in the second step. In this phase, students investigated the scientific knowledge needed for solving the problem phase. During the four-lesson hour, the scientific knowledge collected from books and mini activity, imaginary organism activity implemented to understand structure and functions in nature. Collected scientific knowledge was used for developing possible solutions in the step three. During the one-lesson hour, students developed solutions individually in their team for the one-hour lesson. They explained their solution proposals by using criteria and constraints. The developed possible solutions were discussed in their team in order to choose the best solution proposal. In the step of selecting the best possible solution, students used a decision-making matrix to decide the best one by using criteria and constraints during the one-lesson hour. The chosen solution by the team used for constructing a model/prototype in the step five. In this period, students developed their models in the two-lesson hour. Developed models were tested/controlled by using a checklist according to the criteria and constraints in the step of test and evaluate the solution after then they presented their models in the phase of communicate the solution during the one-lesson hour. In the last step of redesign, each team improved its solutions regarding the feedback from teacher and students during the one-lesson hour.

Description of Performance Assessment Rubrics

The Imaginary Organism Assessment Rubric (see Appendix 6) was developed for assessing the models that students developed to describe their imaginary organisms' adaptations based on the mechanism between structure and function on the range of 0 and 24 points. The first sub-dimension of the rubric titled Developing and Using Models indicates the progression of students from level 0 to 3 for developing an accurate model in terms of drawing, description and identification of their imaginary organisms. The second sub-dimension of the rubric titled Structure and Function indicates the progression of students from level 0 to 3 for accurately explaining the relation between proposed structure and function that an imaginary organism has for each adaptation.

The Biomimicry Design Task Assessment Rubric (see Appendix 8) was developed for assessing the prototype biomimicry models that students developed to solve a human problem as regards to eight categories that indicates the progression of students from level 0 to 3 providing analysis of the engineering design process on the range of 0 and 48 points. The categories of the rubric developed based on the engineering design steps of Massachusetts Science and Technology/Engineering Curriculum Framework (Massachusetts Department of Education, 2006) in order to assess students' achievement on engineering design steps.

Description of Evaluation Form

Biomimicry STEM Activity Reflective Evaluation Form (see Appendix 9) consists of open-ended questions to realize students' perceptions and opinions about the whole process of engineering design task. The form was applied for all the students of 21 at the end of the study. Six students were interviewed with the similar questions because of their short or unclear answers.

FINDINGS

Findings on the Imaginary Organism Assessment Rubric

Through the science activities as performance expectations, students are expected to query the structures of organisms and relate their functions, create an imaginary organism, and communicate the way of thinking by drawing, labeling, and explaining. Students developed an imaginary model organism by describing the traits and adaptations on it as well as by describing its scientific group and scientific name. The drawings and created imaginary organisms that each group developed are displayed in Appendix 10. The Imaginary Organism Assessment Rubric was used for assessing students' science learning through the worksheets completed during the whole process and created imaginary model organisms' adaptations. After each group presented their imaginary model organism, the teacher completed the rubric. The Table 2 indicates the overall score that each group gets for their imaginary model organism. As regard to the table each team has average high score that indicates students' understanding the role of the structure-function relationship in organisms' adaptations. When the presented imaginary organisms were considered, students were able to describe their organisms' structures, feeding type, predators, and habitat, physical and behavioral adaptations.

Table 2.
Imaginary organism assessment rubric scores

Dimension	Criteria	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
	Name and classification	3	3	2	3	2	1
Developing and using models	Drawings	2	2	2	3	2	3
	Description	3	3	3	3	3	3
	Nutrition	3	3	2	3	3	3
	Defending from predators	2	3	2	3	3	3
Structure and Function	Communication	2	2	3	3	2	3
	Mating	0	3	2	2	3	3
	Habitat	2	3	3	3	3	3
Total Score	…/24	17	22	19	23	21	22

Findings on the Biomimicry Design Task Assessment Rubric

Through the engineering design activities as performance expectations, students are expected to describe how they would adapt an organism's structure to solve a human problem. Appendix 11 displays the sample drawings of great designs for the biomimicry models that each group proposed to solve a human problem. The biomimicry models that each group developed are displayed in Appendix 12. The Biomimicry Design Task Assessment Rubric was used to evaluate the students' prototype biomimicry models at eight categories. After each team presented their biomimicry designs to the class, the teacher completed the rubric. Table 3 indicates the scores for eight categories and for overall that each group has for their biomimicry model. The students' scores on the categories of 'Identify the need or the problem' including identifying constraint and criteria and 'Research the need or the problem' are lower than other steps of the engineering design process. Although all groups have the lowest score in identifying and research the problem, they seem to develop an understanding about engineering design as a whole process. When the developed biomimicry models were considered, they

were able to reflect the complementary relationship between structure and function in relation to the behaviors of organism in their design solutions for a human problem. The Team 1's biomimicry model named as fishing-net aims to help people fish inspired from pelican's beak. The Team 2's biomimicry model named as non-slip socks aims to prevent people from slipping inspired from gecko's toe pads. The Team 3's biomimicry model named as trap aims to help people hunt inspired from Venus flytrap. The Team 4's biomimicry model named as bat's ear headset aims to help deaf people hear or use in sound insulation inspired from bat's ears. The Team 5's biomimicry model named as hook aims to help people carry out heavy things inspired from falcon's claw. The Team 6's biomimicry model named as sew-burry aims to help people plant seed easily inspired from chicken's beak.

Table 3.
The biomimicry design task assessment rubric scores

Engineering Design Process	Criteria	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
Identify the need or the problem	Identification of need/problem	2	1	2	2	3	2
	Identification criteria and constraints	1	1	1	1	1	2
Research the need or the problem	Identifying the information needed to solve the need / problem	1	1	2	2	1	1
	Identifying how the information obtained will be used to solve a human needs / problem	1	1	2	1	1	2
Develop possible solution(s)	Suggestion of solution for needs / problem	1	1	3	2	1	3
	Drawing blueprint for solution proposal	2	2	2	2	2	3
Select the best solution(s)	Determining the pros and cons of solution proposals 11	1	1	2	2	2	3
	Explanation of the reasons (positive /negative aspects, criteria and constraints) of the selection the best proposal	1	1	2	2	2	2
Construct a prototype	Building a model / prototype for the solution proposal	2	2	3	3	2	3
	Using the materials that meet the criteria and constraints for the model / prototype	3	3	3	3	3	2
Test and evaluate the solution(s)	Testing how the model or prototype solves the problem/need	1	2	3	3	2	3
	Explanation of the test results using a scientific language	1	2	3	2	2	2
Communicate the solution(s)	Explaining how designs can solve human needs / problems	2	2	3	2	2	3
	Determining the structures of living things in their designs and how they are used in their functions	1	2	3	2	2	3
Redesign	Describing the required improvements for their design	2	2	3	2	2	2
	Improving designs according to the data and evaluations obtained as a result of testing and sharing solutions	1	2	3	2	1	2
Total Score	…/48	23	26	40	33	29	38

Findings on the Reflective Evaluation Form

The prominent findings on the examination of the students' reflection by applying open-ended questions and semi-structured interviews about the activity are summarized under the four themes as following; *challenges, team working, learning in activity, and likes and dislikes.* The students expressed that they faced with the challenges while building their model/prototype (n=11) and team working such as indecisions (n=4) and disputes (n=2) within the team (n=9), and the selection of the best solution (n=3). Students usually expressed difficulties while practicing the mechanism in their model. For example, one of the students reported that "*the mechanism inside our design that is the point we had difficulty choosing which material to use"* (T6.S4). As an example for group challenges T1.S6 reported that "*We had a lot of difficulty because each design solution was very good*" Similarly, T2.S2 reported that "*We could not make a decision in the team.*" Another student member in the same group explained the reason for the problems that they had faced in the group work as "*Because we*

have a lot of ideas in our mind. Which one we should apply? Which one is more beautiful? Which one works well? So, we had some confusion in the group" (T2.S1).

On the other hand, they explained how they overcome the challenges while working within team members including collaborating, brainstorming, generating new ideas, discussing, helping each other and finding a solution together (n=11). For example, T3.S3 stated that "*Two friends in our group did not work well at the first. They were working as if they had been in another group. It frustrated me. We could not work well. But we had an agreement with them. After agreement we would work together harder.*" Besides they expressed that using different materials (n=1), by trying (n=1), planning study (n=1), using criteria (n=1) and working without giving up (n=1) helps them to cope with the challenges. In the probing interview about how they cope with an unstable condition T4.S1 reported that "*We were in trouble while choosing the best solution. We used the criteria and constraints to choose the best solution.*"

Students were also asked how they worked as a team in the separate question. Although the students mainly explained they work in a harmony as a team with cooperation and helping with each other (n=15), some of them explained they could not work in a team because of struggling with team members and failing to decide together (n=6) in parallel to the statements in the theme of the challenges. The students' answers indicates that they work in a harmony in their group are as follows. T3.S4 stated that "*We were debating, but we worked very well.*" Similarly, T5.S1 reported that "*We worked very well in our team. Only we had a trouble while choosing which structure of the animal we used to design task."* According to the teachers' field notes, only in two groups there were serious disputes in team working. Even though six students stated that they could not work as a team only two students wanted to change their group.

The students in the theme of learning in the activity pointed that they learnt about the engineering including how engineers work and nature of engineering (n=6), structure and function in organisms (n=9), working in a team (n=3), scientific inquiry (n=3), building a model/prototype (n=3), knowledge about the living things (n=1), importance of doing research (n=1), decision making (n=1), finding imperfection in design (n=1), understanding project (n=1) and entrepreneurship (n=1). For example, T3.S2 stated that *"We used structure and function in order to find a solution for human needs. Engineers use biomimicry as we use.*" Similarly, T1.S2 stated that "*We learned species of living things, engineering and entrepreneurship."* The students indicated that their skills to learn science and scientific inquiry in obtaining scientific knowledge developed. For example, T2.S2 reported that *"We learned structures of the animals from TUBITAK books. There was a worksheet that we were used for writing what we learn from the book. Using that knowledge, for example Gecko's structure and function we inspired to design not-slip socks."* Also, students reported that they learned working in the team. As an example, T2.S1 reported that *"We learned how we can make a decision together and working together."*

About the themes of likes versus dislikes about the activity the findings indicated that students liked everything in the activity (n=17), the design task and building model/prototype (n=6), learning about animals (n=5), team working (n=2), and brainstorming (n=2). Overall, the students seem to have positive perceptions towards the activity. The collected data by using semi-structured interview supports this finding. For example, one of students (T3.S1) stated that *"This activity is both fun and instructive."* Another student (T3.S2) pointed that *"The idea of the design task was very beautiful. To bring the life the idea made us very happy."* Although majority of the students' answers indicated that they like every section in the activity, few of them stated unfavorable sections of the activity including difficulties on some parts of worksheet (n=1), building a design solution (n=1) and drawing of the model/prototype (n=1). Examination of the students' respond in the theme of suggestions for implementation of the activity indicates that the majority of students did not to change anything (n=15). On the other hand, few students wanted to change such as their team (n=2), design task (n=2) and writing task (n=1). For example, T1.S2 stated that "*The design task was very hard. It would be*

better if it would be easier." Another student T2.S2 reported that "*I would like to change my team members.*"

DISCUSSION AND CONCLUSION

In achieving science goals, students were expected to make observations and conduct investigations to build an understanding of animal behaviors and adaptations. Overall, the students expressed positive science experiences and they were able to identify the structure and its function properly for coherent science learning. In deepening their understanding about nature, the imaginary organism activity it is an effective and fun way to display the relationship between structures and function in organisms for 5th graders. In the similar line, Keçeci, Alan, and Kırbağ Zengin (2017) emphasized the role of inquiry learning to help students integrate STEM disciplines by involving them actively and enjoyable in the science learning process. Another study by Tekerek and Tekerek (2018) supported that instructional materials developed by integrating different disciplines provide an efficient teaching and learning tool.

The results on the biomimicry design task assessment rubric indicate that students can describe how they would adapt the organism's structure to solve the human problem for the engineering design process. But, the students' scores on the first steps of identifying a need or problem including determining criteria and constraints and what they need to know about scientific knowledge to realize their design task are lower than other steps of the engineering design process. Likewise, Karakaya, Yantırı, Yılmaz, and Yılmaz (2019) in their study with primary students emphasized shortage of time, materials and information as the problems in the realization of STEM activities. Students' struggles while identifying constraints and criteria were also realized on written documents such that they mixed them and used interchangeably.

The qualitative data obtained from students' responses to reflective open-ended questions and transcribed interviews also confirm these findings such that level of students' literacy about structure and function, perception of the engineering and understanding engineering design process were improved. Related with the engineering design process they gained mainly an ability to build a model/prototype. These outcomes are consistent with many studies in attempt to further development of students engineering design process skills and understanding engineering throughout STEM implications (Baran, Canbazoğlu-Bilici, & Mesutoğlu, 2015; Duban, Aydoğdu, & Kolsuz, 2018; Ergün & Külekçi, 2019; Özcan & Koca, 2019). Even more striking result is that students can manage to incorporate biomimicry into their design solutions by the way of the complementary relationship between structure and function in organisms. Structure-function model to translate biomimicry into bio-inspired design solutions has been pointed in growing large body of the design based educational literature (Cohen, Reich, & Greenberg, 2014; Hmelo et al., 2000; Stevens, De Vries, Bos, & Kopnina, 2019).

As a result of the examining the further findings on the qualitative data we can conclude that they had challenges most with working in a team due to the conflicts and building model/prototype for engineering design process. The challenges may stem from background of the students. It can be seen that it is inevitable for students to face these difficulties because they may have experienced STEM activity and teamwork for the first time in their educational lives. Examining the related literature in the similar context usually support this finding. For example, Özcan and Koca (2019) stated the problems faced with engineering design process as troubles in utilizing the technology, troubles in putting the designs into practice and not respecting the ideas in the group. Similarly, Karakaya et al., (2019) reported as the most revealed problem by the students as the designing and implementing.

The current study also revealed that even the students' answers pointed that working in a team was challenging, they coped with these challenges by working in a harmony as a team. Another supporting idea is that only two students wanted to change their teams when they were asked what you would like

to change in this study. It can be interpreted that they were learning in the process how to work effectively with their peers in the team. As it is supposed to be they discussed each design solution regarding pros and cons by considering criteria and constrains. This gave them an opportunity to see weakness versus strengths of their design solutions. This finding is consistent with the previous STEM studies in which collaboration has been emerged as prominent 21st century skills that students acquired through the design process (Bolatlı & Korucu, 2018; Karakaya et al., 2019; Özcan & Koca, 2019; Özçelik & Akgündüz, 2018).

Based on the overall findings of the study, it can be concluded that the biomimicry STEM activity provides student actively involved in science and engineering practices. Students were defined the problem, collected data about living things by reading scientific books or watching documentaries or observing living things, collected and interpreted data, developed models, explained their design solutions by using scientific knowledge, and communicating ideas and their findings with their peers. As a core result of the study, biomimicry STEM activity provided students conceptualize the adaptations of living things based on the relationship between structure and function while experiencing the engineering design process. That's why, biomimicry should be considered precisely in science teaching curriculum in terms of providing an opportunity to integrate interdisciplinary STEM into the classroom environment (Gardner, 2012; Pauls, 2017; Yakışan & Velioğlu, 2019; Yıldırım, 2019).

Taking consideration advantage of the features of biomimicry in STEM education can provide a unique learning opportunity for students to understand both scientific concepts and engineering design principles. Moreover, using the relationship between structure and function is an effective way to understand biomimicry and engage students as a bioengineer into engineering design process because of the natural connections between natural and designed world. So, much more research should be needed to explore biomimicry strategies to inspire students in solving human made problems for more sustainable future.

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Ethical Approval: For the research, the necessary permission was obtained according to board decision, dated 05/02/2019 and 2439445 numbered from the Research Evaluation and Investigation Committee of the Antalya National Education Directorate. Written informed parental consent form was obtained for all students.

REFERENCES

Aşık, G, Doğança Küçük, Z., Helvacı, B. & Çorlu, M. S. (2017). Integrated teaching project: A sustainable approach to teacher education. *Turkish Journal of Education*, *6*(4), 200-215. DOI: 10.19128/turje.332731

Aziz, M. S., & El sherif, A. Y. (2016). Biomimicry as an approach for bio-inspired structure with the aid of computation. *Alexandria Engineering Journal*, *55*, 707-714. DOI: 10.1016/j.aej.2015.10.015

Baran, E., Canbazoğlu-Bilici, S., & Mesutoğlu, C. (2015). Science, technology, engineering, and mathematics (STEM) public service announcement (PSA) development activity. *Journal of Inquiry Based Activities, 5*(2), 60-69.

Benyus, J. M. (2002). *Biomimicry: Innovation inspired by nature*. New York: Harper Collins e-books.

Biomimicry Institute (2010). What is biomimicry? Retrieved from https://biomimicry.org/what-is-biomimicry-3/

Bolatlı, Z., & Korucu, A. T. (2018). Secondary school students' feedback on course processing and collaborative learning with web 2.0 tools-supported STEM activities. *Bartin University Journal of Faculty of Education, 7*(2), 456-478. DOI: 10.14686/buefad.358488

Bybee, R. W. (2013). The next generation science standards and the life sciences. *The Science Teacher, 80*(2), 25–32.

Cohen, Y. H., Reich, Y., & Greenberg, S. (2014). Biomimetics: Structure–function patterns approach. *Journal of Mechanical Design, 136*(11), 111108-1-111108-11.

Corlu, M. S., Capraro, R. M. & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers for the age of innovation. *Education and Science, 39*(171), 74-85.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). Thousand Oaks, CA: Sage.

Duban, N., Aydoğdu, B., & Kolsuz, S. (2018). STEAM implementations for elementary school students in Turkey. *Journal of STEM Arts, Crafts, and Constructions, 3*(2), 41-58.

Duschl, R. A. (2012). The second dimension-crosscutting concepts. Retrieved from http://static.nsta.org/ngss/resources/201202_Framework-Duschl.pdf

Ergün, A., & Külekçi, E. (2019). The effect of problem-based STEM education on the perception of 5th grade students of engineering, engineers and technology. *Pedagogical Research, 4*(3). DOI: 10.29333/pr/5842

Gardner, G. E. (2012). Using biomimicry to engage students in a design-based learning activity. *The American Biology Teacher, 74*(3), 182-184.

Guzey, S.S., Tank, K., Wang, H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School Science and Mathematics, 114*(3), 139-149. DOI: 10.1111/ssm.12061

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences, 9*(3), 247–298. DOI: 10.1207/S15327809JLS0903

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert–novice understanding of complex systems. *Journal of the Learning Sciences, 16*(3), 307-331. DOI: 10.1080/10508400701413401

Hmelo-Silver, C. E., Jordan, R., Liu, L., Gray, S., Demeter, M., Rugaber, S., & Goel, A. (2008). Focusing on function: Thinking below the surface of complex natural systems. *Science Scope, 31*(9), 27–35.

Hwang, J., Jeong, Y., Park, J.M., Lee, K. H., Hong, J. W., & Choi, J. (2015). Biomimetics: Forecasting the future of science, engineering, and medicine. *International Journal of Nanomedicine, 10*, 5701–5713.

Karakaya, F., Yantırı, H., Yılmaz, G., & Yılmaz M. (2019). Determination of primary school students' views about STEM activities: Example of 4th grade. *International Journal of Turkish Education Sciences, 7*(13), 1-14.

Keçeci, G., Alan, B., & Kırbağ Zengin, F. (2017). STEM education practices with 5th grade students [Special issue]. *Ahi Evran University Journal of Kırşehir Educational Faculty, 18*, 1-17.

Kohn, K.P., Underwood, S. M., & Cooper, M. M. (2018). Connecting structure-property and structure-function relationships across the disciplines of chemistry and biology: Exploring student perceptions. *CBE-Life Sciences Education, 17*(2). DOI: 10.1187/cbe.18-01-0004

Lederman, N. G. (2019). Illinois institute of technology college of science/bird activity. Retrieved from https://science.iit.edu/sites/science/files/elements/mse/hstp/pdfs/Scenario-Birdactivity.pdf.

Massachusetts Department of Education. (2006). Massachusetts science and technology/engineering curriculum framework. Retrieved from http://www.doe.mass.edu/frameworks/scitech/1006.doc

Ministry of National Education. (2018). *Elementary and middle school (3, 4, 5, 6, 7, and 8th grades) science curriculum*. Ankara: Board of Education and Training.

Moore, T.J., Stohlmann, M.S., Wang, H.H., Tank, K.M., Glancy, A.W., & Roehrig, G.H. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in precollege settings: Research into practice* (pp. 35–60). West Lafayette, IN: Purdue Press.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. (2013a). *Next generation science standards: For states by states.* Washington, DC: The National Academies Press.

NGSS Lead States. (2013b). *Next generation science standards: For states by states* (Vol:2 Appendixes). Washington, DC: The National Academies Press.

Öner, A. T., Navruz, B., Biçer, A., Peterson, C. A., Capraro, R.M., & Capraro, M.M. (2014). T-STEM academies' academic performance examination by education service centers: A Longitudinal Study. *Turkish Journal of Education, 3*(4), 40-51.

Özcan, H., & Koca, E. (2019). The impact of teaching the subject "pressure" with STEM approach on the academic achievements of the secondary school 7th grade students and their attitudes towards STEM. *Education and Science*, *44*, 201-227. DOI: 10.15390/EB.2019.7902

Özçelik, A., & Akgündüz, D. (2018). Evaluation of gifted/talented students' out-of-school STEM education. *Trakya University Journal of Education Faculty*, *8*(2), 334-351. DOI: 10.24315/trkefd.331579

Patton, M. Q. (2014). *Qualitative evaluation and research methods*: *Integrating theory and practice*. Sage Publications.

Pauls, S. (2017). Biomimicry a "natural lesson" in STEAM. *The STEAM Journal*, *3*(1). DOI: 10.5642/steam.20170301.33

Pauw, I., Kandachar, P., Karana,E., Peck, D., & Wever, R. (2010, October 25-29). *Nature inspired design: Strategies towards sustainability*. Paper presented at Knowledge Collaboration & Learning for Sustainable Innovation: The European Roundtable on Sustainable Consumption and Production (ERSCP) /Environmental Management for Sustainable Universities (EMSU) Conference, Rotterdam, Delft, The Netherlands.

Stevens, L., De Vries, M.J., Bos, M.J.W., & Kopnina, H. (2019). Biomimicry design education essentials. In W. Sandro, S. Benjamin, & Gon (Eds.), *Proceedings of the 22nd International Conference on Engineering Design (ICED19).* (pp. 459-468). Delft, The Netherlands, 5-8 August. DOI:10.1017/dsi.2019.49

Tekerek, M., & Tekerek, B. (2018). Integrated instructional material and development process. *Turkish Journal of Education*, *7*(3), 156-168. DOI:10.19128/turje.362491.

Wendell, K., Connolly, K., Wright, C., Jarvin, L., Rogers, C., Barnett, M., & Marulcu, I. (2010, October). *Incorporating engineering design into elementary school science curricula*. Paper presented at the Annual Meeting of American Society for Engineering Education, Singapore.

Yakışan, M., & Velioğlu, D. (2019). The analysis of the drawings of the 4th grade students towards biomimicry perceptions. *Gazi University Journal of Gazi Educational Faculty (GUJGEF)*, *39*(2), 727- 753. DOI: 10.17152/gefad.547807

Yıldırım, B. (2019). The opinions of pre-service science teachers about biomimicry practices in STEM education. *Gazi University Journal of Gazi Educational Faculty (GUJGEF)*, *39*(1), 63-90.

Yildirim, A., & Simsek, H. (2006). *Qualitative research methods in social sciences* (5th ed.). Ankara: Seçkin Publications.

APPENDIX 1

Biomimicry Design Task

Nature has been an inspiration for art, design, and innovation for a long time. For example, the wing structure of birds was a guide for humankind who had dreamt of flight and led Wright brothers to invent the plane. The science that brings solutions to problems by mimicking the models and systems in nature or different characteristics of living things is called Biomimicry. Today, applications of biomimicry are used in various fields such as science, technology, art, architecture, artificial intelligence, nanotechnology, robotics, industry, military research, and transportation. A biomimicry company is looking for solutions to human problems by using the characteristics of living things. Company officials in need of new ideas in this field are organizing a competition. As a biomimicry expert, you are expected to solve one of humanity problems by mimicking how plants and animals use their internal and external structures to grow, survive, and meet all their other needs.

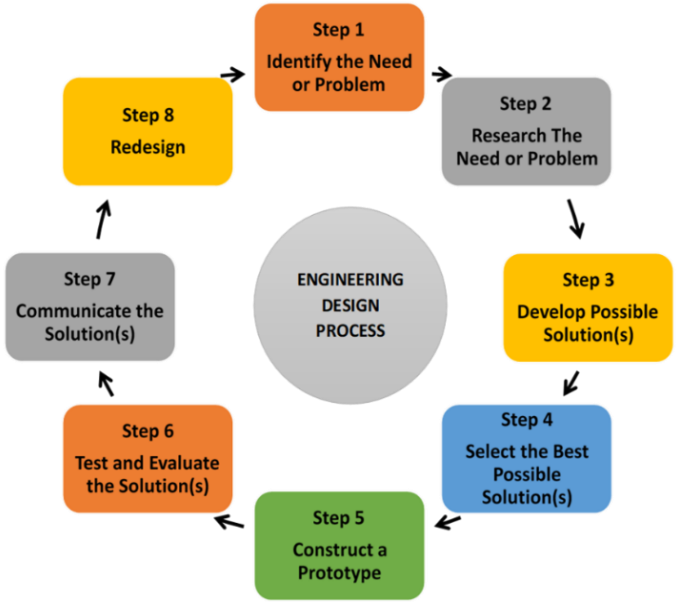
To this end, you and your team are expected to observe the structures of living things, collect information about the functions of these structures, and then develop a design to solve a human problem using the complementary relationship between structure and function in organisms. Once you have completed your design, you will present your work to a board of scientists and engineers. In your presentation, you will explain how you created your design by describing the structure of the living thing you have determined and the function of this structure, and how you used these to solve humanity's problems. The specifications of the competition are given below:

Specifications of the competition

1) Your design must be created by mimicking at least one structure belonging to the organism.
2) Your design must address at least one of human problems.
3) No harmful substances should be used in your design.
4) You can use all kinds of materials in your design, especially recycled materials.

**Through direct observation, watching documentaries or reading scientific books such as publications by TUBITAK, you will determine which organism you will use in your design, the structures belonging to the organism and how they use these structures to survive based on evidence. You can also use other resources (webpages, available printed resources).

You will use the following engineering cycle while performing your design task;



APPENDIX 2

Structure and Function Worksheet

Name-Surname: …….

Summarize the structures that help the survival of organisms you have found in your research and their functions in the table below.

The source you collected the information	Name of the organism	Structure belonging to the organism and its characteristics	Function of the structure	Benefits of this function for the organism	Which humanity problem you can solve by using the characteristic of this structure?

APPENDIX 3

Imaginary Organism's Adaptations

Name of your Team: ……

Think of an imaginary organism with your teammates. You can use the structures and functions of different organisms each of you learned in the first stage while deciding the characteristics of the imaginary organism. Explain the structures you have chosen for your imaginary organism, the functions of these structures and their benefits to the organism using the table below.

Explanations / Structures	Name and characteristic of the structure (wing, tail, mouth, teeth, root, leaf, trunk, eye, etc.)	Function of the structure	Explain why you chose this structure (What kind of benefit this structure provides for the survival of your organism?)
What external structures will your imaginary organism have?			
What internal structures will your imaginary organism have?			
What structures will your imaginary organism have to find and eat its food?			
What structures will your imaginary organism have to protect itself from its enemies?			
What structures will your imaginary organism have to communicate with its friends and offspring?			
What structures will your imaginary organism will have to find a mate?			
You can also add…			

APPENDIX 4

Drawing and Labeling the Imaginary Organism

Name of your Team: ……

Draw the picture of your organism you have imagined. While drawing your picture, be sure to label the structures of the organism you have imagined in detail.
Scientific name of your imaginary organism: ----------
Write a story or news that introduces your imaginary organism to the world of science:
---------- ------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ------- ---------- -- ---------- ------- ----------

APPENDIX 5

Introducing Imaginary Organism

Name of your Team: ……

You will introduce your imaginary organism to the world of science. To do this, you will form the following species tag. In this tag, you can mention the structures and characteristics of your organism, the group its scientifically belong, habitat, nest, food sources, enemies, etc.

Scientific name of our organism: (It must be a Latin name called binomial nomenclature consisting of two names. The first name defines *genus* and the second a name defines *species*. The entire name is italicized (e.g., *Homo sapiens*) and abbreviated by the first letter of the genus name capitalized (e.g., *H. sapiens*).	
The scientific group our organism belongs: Specify whether it is a plant, an animal, a microscopic organism or fungi. If it is a plant, is it vascular or nonvascular? If it is an animal, is it vertebrate or invertebrate? If it is vertebrate, is it a mammal, a fish, a frog, a reptile or a bird? If it is invertebrate, is it an insect, a spider, a worm, a snail, etc.? If it can be in multiple groups, specify.	
Body parts of our organism have: (Tail, wing, trunk, mouth, beak, leaf, root, legs, ears, etc.)	
The habitat of our organism lives: (Desert, sea, forest, poles, etc.)	
The nest and its characteristics of our organism:	
The nutrient sources of our organism:	
The dangers awaiting our organism:	
The strongest feature of our organism:	
The weakest feature of our organism:	

APPENDIX 6

Imaginary Organism Assessment Rubric

Name of Team: ……

Dimension	Criteria	Imaginary Organism Assessment Rubric			
		0	1	2	3
Developing and using models	Name and classification of organism	No evidence of the name or classification of the organism	The organism is named but not classified.	The organism is classified but not named.	The organism is named and classified
	Drawing and labeling	No evidence of drawing of the organism	Drawing of the organism is unclear and lack of finer details.	Drawing of the organism is clear but lack of finer details.	Drawing of the organism is clear and has finer details.
	Description	No evidence of description of the organism	Description of the organism does not match the drawing.	Description of the organism does not exactly match the drawing.	Description of the organism matches the drawing.
Structure and function	Nutrition	No evidence of relation between structure and function	The organism cannot consume nutrients with its modelled structures.	The organism hardly consumes nutrients with its modelled structures.	The organism consumes nutrients easily with its modelled structures.
	Defending from predators	No evidence of relation between structure and function	The organism cannot protect itself from its predators with its modelled structures.	The organism hardly protects itself from its predators with its modelled structures.	The organism can protect itself easily from its predators with its modelled structures.
	Communication	No evidence of relation between structure and function	The organism cannot communicate with its modelled structures.	The organism can hardly communicate with its modelled structures.	The organism can communicate easily with its modelled structures.
	Mating	No evidence of relation between structure and function	The organism cannot find a mate with its modelled structures.	The organism hardly finds a mate with its modelled structures.	The organism can find a mate easily with its modelled structures.
	Habitat	No evidence of relation between structure and function	The organism cannot survive with its modelled structures in its habitat.	The organism hardly survives with its modelled structures in its habitat.	The organism can survive easily with its modelled structures in its habitat.
Total Score	…/24				

APPENDIX 7

Great Design Task Draft Drawing

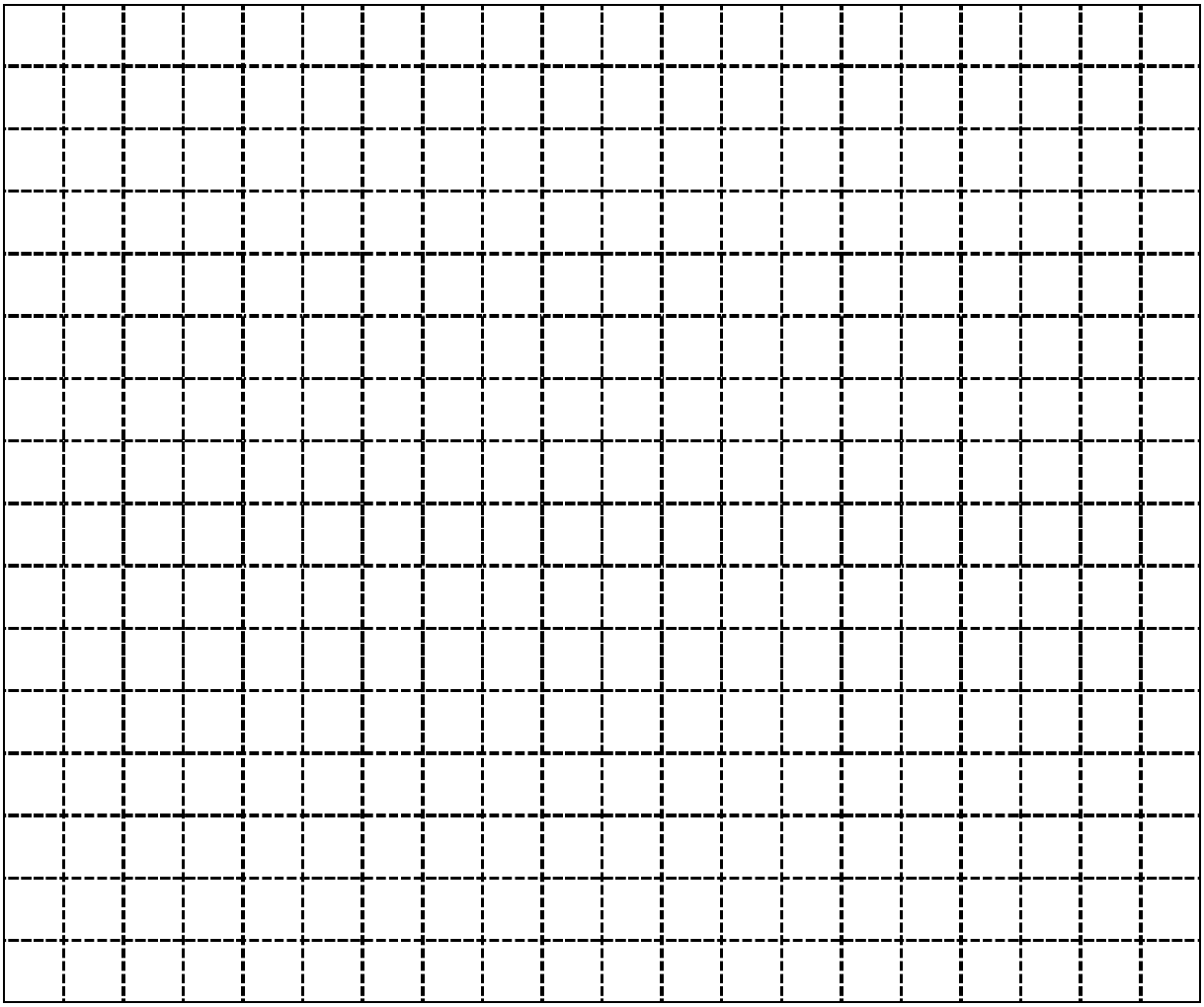
Name of your Team: ……

At the beginning of the unit, read the great design task you were given again. You will apply the scientific knowledge you have learned up to this stage on your great designing task. Answer the following questions and draw the sketch of the design you have made with your team below.

While creating your design, which organisms did you use the structure and the function of?

What human problem will your design solve, and how?

Which materials will you use in which part of your design?



APPENDIX 8

Biomimicry Design Task Assessment Rubric

Engineering Design Process Steps	0	1	2	3
Identify the need/problem	The need/problem was not identified.	The need/problem was defined superficially.	The need/problem was identified.	The need/problem was identified clearly with all details.
	The criteria and constraints were not identified.	Some of the criteria and constraints were identified.	Most of the criteria and constraints were identified.	All the criteria and constraints were identified.
Research the need or the problem	The information needed for the solution of the need/problem was not determined.	Some of the information needed for the solution of the need/problem was defined.	Most of the information needed for the solution of the need/problem was defined.	All the information needed for the solution of the need/problem was defined.
	It was not defined how the collected information would be used to solve the need/problem.	It was superficially defined how the collected information would be used to solve the need/problem.	It was defined how the collected information would be used to solve the need/problem.	It was clearly defined in detail on how the collected information would be used to solve the need/problem.
Develop possible solution(s)	No solution was proposed for the need/problem.	The proposed solution for the need/problem was met the some of the criteria and constraints.	The proposed solution for the need/problem was met most of the criteria and constraints.	The proposed solution for the need/problem was met the all the criteria and constraints.
	No blueprint drawn for proposed solution.	The blueprint was reflected the solution proposal superficially.	The blueprint was reflected the solution proposal.	The blueprint was reflected the solution proposal in detail.
Select the best solution(s)	The pros and cons of proposed solutions were not defined.	Some of the pros and cons of proposed solutions were defined.	Most of the pros and cons of proposed solutions were defined.	All the pros and cons of proposed solutions were defined with details.
	Whether the chosen solution meets the criteria and constraints were not explained.	Some of the reasons for the chosen solution were explained.	Most of the reasons for the chosen solution were explained.	All the reasons for the chosen solution were explained with details.
Construct a prototype	A model/prototype for the solution proposal was not created.	A partially appropriate model/prototype for the solution proposal was created.	An appropriate model/prototype for the solution proposal was created.	A completely appropriate model/prototype for the solution proposal was created.
	The materials that meet the criteria and restrictions for the model/prototype were not used.	The materials that meet part of the criteria and restrictions for the model/prototype were used.	The materials that meet most of the criteria and restrictions for the model/prototype were used.	The materials that meet all the criteria and restrictions for the model/prototype were used.
Test and evaluate the solution(s)	It was not tested how the model/prototype solves the need/problem.	The model/prototype was tested how it would solve the need / problem. Test results were not analyzed.	The model/prototype was tested how it would solve the need/problem. Part of the test results were analyzed	The model/prototype was tested how it would solve the need/problem. All the test results were analyzed completely.
	The data related to the test results were not explained by using scientific language.	Part of the data related to the test results were partly explained by using scientific language.	Most of the data related to the test results were explained by using scientific language.	All the data related to the test results were explained by using scientific language completely with details.
Communicate the solution(s)	It was not explained how the designs would solve the need/problem.	It was partly explained how the designs would solve the need/problem.	It was explained how the designs would solve the need/problem.	It was explained completely how the designs would solve the need/problem with details.
	The structure/structures belonging to living things and how the functions of these structures are utilized were not identified.	The structure/structures belonging to living things and how the functions of these structures are utilized were partly identified.	The structure /structures belonging to living things and how the functions of these structures are utilized were identified.	The structure /structures belonging to living things and how the functions of these structures are utilized were completely identified with details.
Redesign	The need of improvement for designs was not identified.	The need of improvement for design was partly identified.	The need of improvement for design was identified.	The need of improvement for design was identified with details.
	The design was not improved in the light of the data and feedbacks from the test results and the communication of the solutions.	The design was partly improved in the light of the data and feedbacks from the test results and the communication of the solutions.	The design was improved in the light of the data and feedbacks from the test results and the communication of the solutions.	The design was optimally improved in the light of the data and feedbacks from the test results and the communication of the solutions.
Total Score	…/48			

APPENDIX 9

Biomimicry STEM Activity Reflective Evaluation Form

Write your answers to the following questions in the gaps. You can add drawings to explain. You can use the backside of the paper or a separate paper for your drawings.

1. What kind of difficulties did you face when designing your model / prototype?

.....

.....

2. How did you overcome these difficulties?

.....

.....

3. What did you learn in this activity?

.....

.....

4. What did you do to improve your model/prototype?

.....

.....

5. What did you like in this activity?

.....

.....

6. What did you dislike in this activity?

.....

.....

7. Explain how did you work as a team?

.....

.....

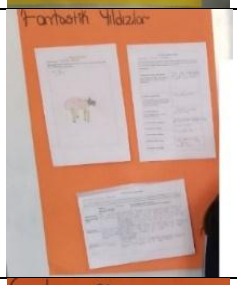
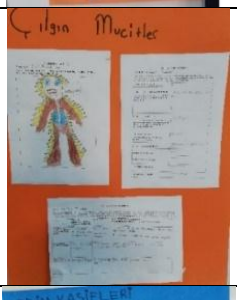
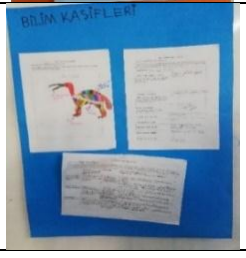
8. What would you like to change in this activity?

.....

.....

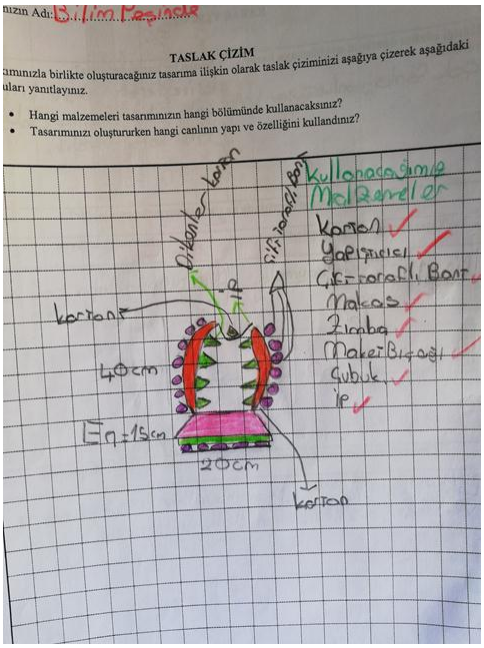
APPENDIX 10

Drawings and Created Imaginary Organisms

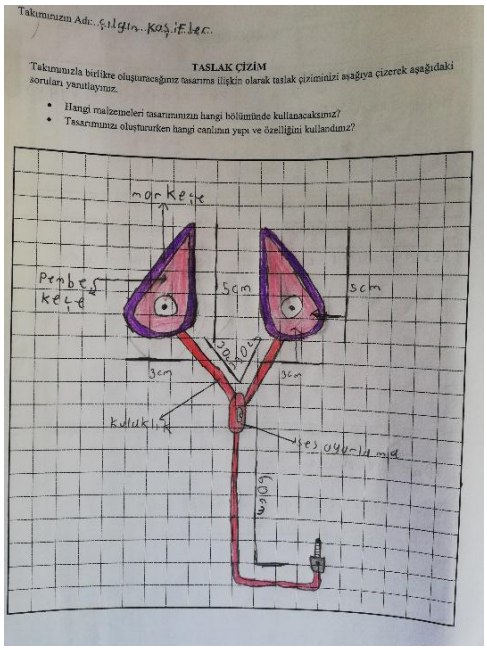
	Introducing the imaginary organism	Modelling the imaginary organism	Presentation of the imaginary organism
Team 1	The flying reptile belongs to reptiles and birds in taxonomy. It has got a tail, wings, a mouth, and legs. It lives in rain forest, nested in shrubs, crawls on the ground and can fly. It has sticky legs like Gecko's pads. It fishes for feeding. The strongest features are poisoned thorn and eyes to help for defending from its predators. The weakest feature is walking slowly. It can hear with sensitive ears and communicate by howling. Its beautiful eyes and mouth, and the capabilities to build a nest can help him to find a mate.		
Team 2	The lion-headed cheetah belongs to mammals in taxonomy. It has a tail, a mouth, a nose, ears, and legs. It has fur to keep itself warm and breathes with lungs. It lives in desert and nested on trees, and hunts for feeding. The strongest features are sharp teeth, paws and legs for hunting and defending from its predators. The greatest danger is human for it. It can communicate using by olfactory ability. This ability also helps to find a mate.		
Team 3	The laying mammal, Babacan has a tail, a mouth, horns, teeth, paws, ears, and black speckles. It is a vertebrate with thick bones. It has a hairy body and thick layer of fat that help for defending its predators. It lives in the forest, and nests in a cave placed on top of the hill. It eats fish and meat. Hunters and its kind of species are hazardous for Babacan's life. While the strongest structures are its poisoned teeth, camouflage, and horns, having a long tail is the weakest. Having eye-catching colors and the feature of changing the colors help him find a mate.		
Team 4	Ulti-bear is an amphibian. It has mouth, lungs and gills, ears, legs, teeth, paws and eyes. Thanks to its lungs and gills, it can breathe in the sea and overland. It is a carnivore and lives in the forest. Its predator is falcon. Its paws and teeth help for defending. The thick fur helps to keep him from the cold weather. The stronger part is gecko eyes so it can see everything. The weakest characteristic is being a coward. Having a beautiful voice helps him find a mate.		
Team 5	Tekakdomeji is a reptile and carnivore. It has got big eyes to see better and hunt, and shred to its prey with sharp teeth. It has got a big shell to be protected by its predators. It lives in a forest and nested in a tree cavity. The strongest structure is its poisoned thorns and the weakest is toenails. The poisoned thorns help to protect its life. Also, it can run fast with its long legs. Tekakdomeji howls like a wolf for communication. With its interesting semblance, it can find a mate easily.		
Team 6	The Red Head belongs to one than more groups in taxonomy. It lives in the forest and nested in a cool place. It has got paws like wolves, and poisoned teeth like bats for hunting. It can change its colors like chameleons and it has got strong shells like a turtle, and flexible spine like a snake. The stronger structures are paws and poisoned teeth, the weakest is its tail. The fishes are its prey. The carnivores are its enemies. The Red Head communicates by barking like dogs. It looks fancy so, it can find a mate.		

APPENDIX 11

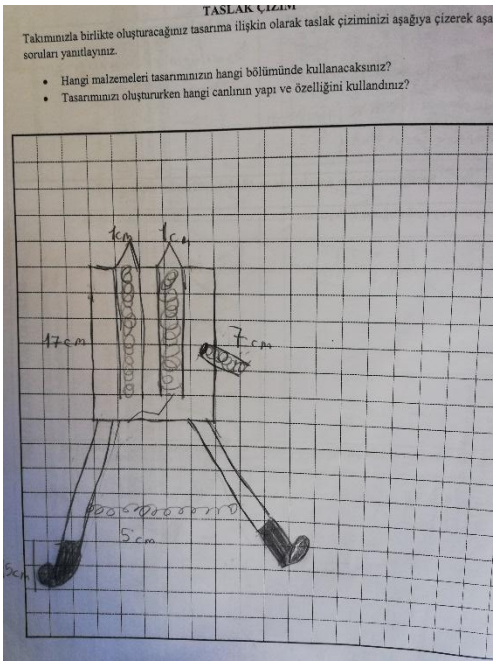
Sample Drawings of Great Design



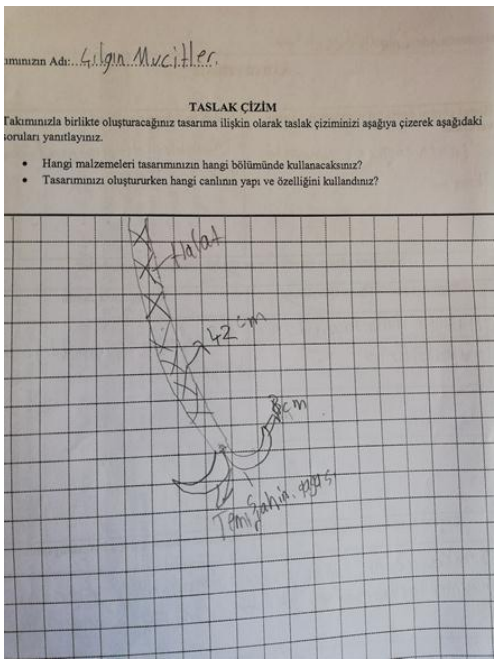
Team 3
Blueprint of the Trap



Team 4
Blueprint of the Bat's Ear Headset



Team 5
Blueprint of the Sew-burry



Team 5
Blueprint of the Hook

APPENDIX 12

Developed Biomimicry Models

Team	The model	The name of the organism used in the design	Structure of the organism	Function of the structure	What kind of human problems solved by your design?	How it works?	What improvement needs in your design?
Team 1 Fishing-net		Pelican	Beak	Scooping - up fish with its large shape.	To help people fish.	Water drains from the holes and fishes remain in the net.	The drainage holes for water were too small. It needs to be larger.
Team 2 Non-slip socks		Gecko	Toe-pads	Climbing on surfaces without slipping or falling down.	To prevent people from slipping and falling.	Sipped silicone prevents slipping.	The slip-proof material under the stocking was thick. It needs to be thinner.
Team 3 Trap		Venus Flytrap	Leaves	Catching the bugs and flies	To help people hunt	When the animal steps on the trap, two leaves are closed.	Need to expand the rim of model
Team 4 Bat's Ear Headset		Bat	Ears	Seeing with ears	To enable deaf people, hear and for sound insulation.	It sends sound waves to human brain.	Size of the headset
Team 5 Hook		Falcon	Claws	Hunting their prey and carry out.	To help people carry heavy things	The load can be hung on the hook and people hold in high.	
Team 6 Sew-burry		Chicken	Beak	Fighting and protecting, Breaking grass and digging the soil.	To help people plant seed easily	The one of chicken's beak digs the hole and another puts the seed and closes the hole.	In our model the beak did not looks like a chicken beak.

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Doğa bilimlerini anlamada en önemli mihenk taşlarından biri 'yapı fonksiyonu belirler' temasıdır. Ulusal Araştırma Konseyi (National Research Council [NRC], 2012) tarafından geliştirilen *K-12 Fen Eğitimi Çerçevesi: Uygulamalar, Kesişen Kavramlar ve Öz Fikirler* reform belgesinde, yapı ve işlev arasındaki ilişki bilim ve mühendislik uygulamaları yoluyla hem kesişen hem de disiplin temel kavramları olarak kabul edilmektedir. Tüm disiplinlerde ve sınıf seviyelerinde temaları birleştiren kesişen kavramlar arasında yer alan yapı ve işlev "bir nesnenin ya da canlının oluşma biçimi ve alt bileşenleri, özelliklerini ve fonksiyonunu belirler" şeklinde tanımlanmaktadır (NRC, 2012, s. 84). Bu çerçevede fizik ve yaşam bilimlerindeki disiplin temel fikirlerinin ana bileşenleri olarak ise yapı ve işlev, sırasıyla 'Maddenin yapısı ve özellikleri' ve 'Yapı ve işlev' içeriğinde yer almaktadır. Diğer taraftan ülkemizde yakın zamanda revize edilen fen programında ise öğrencilerin feni diğer disiplinlerle bütünleştirerek teoriyi pratiğe ve ürüne dönüştürebilmelerine yardımcı olacak fen ve mühendislik uygulamalarına vurgu yapılırken; doğada ya da tasarlanmış dünyada tekrar eden örüntülere ve yapı ve işlev arasındaki ilişkilere herhangi bir sınıf düzeyinde vurgu yapılmamıştır.

Doğa uzun zamandır sanat, tasarım ve yenilik için bir ilham kaynağı olmuştur. Örneğin, uçma hayali kuran insanoğluna kuşların kanat yapıları en büyük yol gösterici olmuş ve bu sayede Wright kardeşler uçağı icat etmişlerdir. Benyus'a (2002) göre milyarlarca yıllık evrimsel süreç, organizmalara canlılıklarını sürdürebilmeleri için inanılmaz çeşitlilikte yapılar, şekiller ve bunlarla ilgili işlevler kazandırmıştır. Bu nedenle, yapı ve fonksiyon arasındaki ilişkiyi anlamak mühendislik tasarımları ve özellikle de biyomimikri tasarımları için kritik bir öneme sahiptir (Cohen, Reich ve Greenberg, 2014). Biyomimikri "doğanın zaman içinde test edilmiş kalıplarını ve stratejilerini taklit ederek insanların sorunlarına sürdürülebilir çözümler arayan yenilikçi bir yaklaşımdır" (Biomimicry Institute, 2010).

Öğrencilerin doğal dünyadaki organizmaları sorgulayarak yapıların işlevlerini ne ölçüde anladıklarıyla ilgili olarak nedensel çıkarımlar yapmaları gerekir. Bu, "mühendislerin doğadaki yapıları insanların ihtiyaçlarını karşılayacak tasarımlar için ilham kaynağı olarak incelerken böyle çıkarımlar yapmalarına" benzer bir yöntemdir (Yeni Nesil Fen Standartları [NGSS] Lead States, 2013b, s.89). Mühendisler doğayı inceleyerek öğrenirler. Bu yüzden yeni tasarım çözümleri için daha mükemmel fikirler elde etmek için doğayı gözlemlerler. Bu durum, günlük yaşamımızda kullandığımız birçok teknolojik aracın neden doğadaki bir mekanizma ile aynı şekilde çalıştığını açıklar. "Doğal ve insan yapımı sistemlerin benzer şekilde işleyişinin, bazı kilit parçaların şekillerine ve ilişkilerine bağlı olduğu kadar üretildikleri malzemelerin özelliklerine de bağlı olduğu" görülebilir (NRC, 2012, s.96). Bu nedenle, doğadaki yapıların amacının veya mekanik fonksiyonunun fen bilgisi derslerinde bir öğrenme çıktısı olarak anlaşılması STEM eğitiminde önemsenmelidir.

STEM eğitiminde biyomimikrinin özelliklerinden yararlanmak, öğrencilere hem bilimsel kavramları hem de mühendislik tasarım ilkelerini anlamalarında eşsiz bir öğrenme fırsatı sunmaktadır. Yapı ve fonksiyon arasındaki ilişkiyi kullanarak biyomimikriyi anlamak, doğal ve insanoğlu tarafından inşaa edilen dünya arasındaki bağlantılar nedeniyle öğrencileri bir biyomühendis olarak mühendislik tasarımına dahil etmenin etkili bir yoludur. Bu çalışma, beşinci sınıf fen bilimleri dersi Canlılar Dünyası ünitesinde yapı ve fonksiyon ilişkisine dayanan biyomimikri STEM etkinliği geliştirmeyi amaçlamaktadır. Çalışmada durum çalışması yöntemi kullanılmış, sosyo ekenomik düzeyi düşük bir devlet ortaokulunda 12 ders boyunca 21 öğrenci ile yürütülmüştür. STEM uygulamaları kapsamında öğrencilerden günlük yaşamdan bir problem belirleyerek canlılara ait yapı ve işlev arasındaki ilişkinin bir taklidi olabilecek biyomimikriyi kullanarak olası bir tasarım çözümü geliştirmeleri istenmiştir. Veriler, açık-uçlu sorular, yarı yapılandırılmış görüşmeler ve mühendislik sürecinin değerlendirilmesi için rubrik kullanılarak toplanmıştır.

Bu çalışmada, öğrencilerin tasarladığı biyomimikri modellerine dayalı veriler, tasarım ve doğal dünyadan alınan ilham arasındaki ilişkilere dayalı olarak tasarım sürecinin bir analizi şeklinde sunulmuştur. Öğrencilerin geliştirdikleri biyomimikri modelleri göz önüne alındığında, öğrencilerin bir organizmayla ilgili yapı ve fonksiyon arasındaki tamamlayıcı ilişki yoluyla biyomimikriyi bir insanlık problemine yönelik tasarım çözümlerine yansıtmayı başardıklarını göstermektedir. Sonuç olarak, biyomimikri STEM etkinlikleri öğrencilerin mühendislik tasarım süreciyle ilgili deneyimler yaşarken canlıların adaptasyonlarını, yapı ve fonksiyon ilişkisine dayalı olarak daha iyi kavramsallaştırmalarını sağlamıştır. Öğrenciler biyomimikri tasarım sürecinde bazı zorluklar yaşamalarına rağmen, çoğu tasarım görevi ve model/prototip yapma dahil olmak üzere etkinlikle ilgili her şeyi beğendiklerini ifade etmişlerdir.

Doğanın sürdürülebilir tasarım çözümleri için bir model olarak kullanılması fen eğitiminde biyomimikrinin kavramsallaştırılmasını kaçınılmaz kılmaktadır. Biyomimikri, öğretmenlere yaşam bilimleri, STEM, yaratıcı problem çözme, tasarım ve sistem düşüncesini harmanlayarak her yaştan öğrencilere ilham verecek bir yol sunarak, eğitimde bir devrim olarak görülebilir (Biomimicry Institute, 2010). Biyomimikri, disiplinlerarası STEM'i sınıf ortamına entegre etme fırsatı sağlaması açısından fen bilgisi öğretim programında yer almalıdır. STEM eğitiminde biyomimikriyi öğretmek doğayı; bilim, teknoloji, mühendislik ve matematikle kesiştirerek bütünleşik bir bağlam sağlayacaktır. Daha sürdürülebilir bir gelecek için, insan kaynaklı sorunların çözümünde öğrencilere ilham verecek biyomimikri stratejilerini öğretmek için daha fazla araştırmaya ihtiyaç vardır.

EK 1

Biyomimikri Tasarım Görevi

Doğa uzun zamandır sanat, tasarım ve yenilik için bir ilham kaynağı olmuştur. Örneğin, uçma hayali kuran insanoğluna kuşların kanat yapıları en büyük yol gösterici olmuş ve bu sayede Wright kardeşler uçağı icat etmişlerdir. İnsanların ihtiyaç duyduğu problemlere doğadaki modelleri, sistemleri ya da canlılara ait farklı özellikleri taklit ederek tasarım çözümleri geliştiren bilim dalına Biyomimikri adı verilir. Biyomimikri uygulamaları günümüzde bilim, teknoloji, sanat, mimari, yapay zekâ, nanoteknoloji, robotik, endüstri, askeri araştırmalar, ulaşım gibi birçok alanda kullanılmaktadır.

Bir biyomimikri şirketi canlıların özelliklerini kullanarak insanların sorunlarına çözüm aramaktadır. Bu alanda yeni fikirlere ihtiyaç duyan şirket yetkilileri bir yarışma düzenler. Bir biyomimikri uzmanı olarak sizden beklenen; bitkilerin ve hayvanların sahip oldukları iç ve dış yapılarını büyümek, hayatta kalmak ve diğer tüm ihtiyaçlarını karşılamak için nasıl kullandıklarını taklit ederek insanlığın bir problemi için çözüm üretmenizdir.

Bu amaçla sizlerden takımınızla birlikte canlıların sahip oldukları yapıları gözlemlemeniz, bu yapıların işlevlerine ilişkin bilgi toplamanız sonra bu yapıları ve işlevleri kullanarak insanların bir problemini çözmek için tasarım yapmanız beklenmektedir.

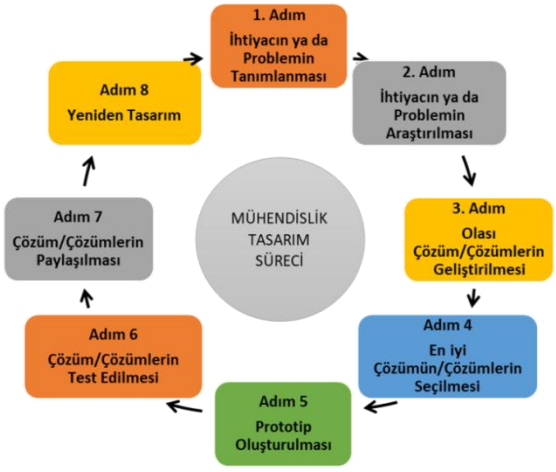
Tasarımınızı tamamladıktan sonra yaptığınız çalışmayı bilim insanları ve mühendislerden oluşan bir kurula sunacaksınız. Sunumunuzda canlıya ait yapı ve bu yapının işlevini açıklayarak tasarımınızı nasıl oluşturduğunuzu, bunları insanların sorunlarını çözmek için nasıl kullandığınızı açıklayacaksınız. Yarışma şartnamesi aşağıda verilmiştir:

Yarışma Şartnamesi

1- Tasarımınız bir canlıya ait en az bir yapının işlevini taklit ederek oluşturulmalıdır.
2- Tasarımınız insanların sorunlarından en az bir tanesine çözüm getirmelidir.
3- Tasarımınızda insan sağlığına zararlı madde kullanılmamalıdır.
4- Tasarımınızda geri dönüşüm malzemeleri başta olmak üzere her türlü malzemeyi kullanabilirsiniz.

**Tasarımınızda doğrudan gözlemleyerek ya da izlediğiniz belgesellerden, TÜBİTAK yayınları gibi okuduğunuz bilimsel kitaplardan canlıları, canlılara ait yapıları ve canlıların bu yapıları hayatta kalmak için nasıl kullandıklarını kanıta dayalı olarak belirleyeceksiniz. Bununla birlikte diğer kaynaklardan da (çevrimiçi sayfalar, ulaşabileceğiniz basılı kaynaklar) yararlanabilirsiniz.

Tasarım görevinizi gerçekleştirirken aşağıdaki mühendislik döngüsünü kullanacaksınız;



EK 2

Yapı ve İşlev Çalışma Kâğıdı

Adınız Soyadınız: …….

Okuduğunuz ve araştırdığınız kaynaklardan canlıların hayatta kalmasına yardımcı olan yapıları ve bu yapıların işlevlerini aşağıdaki tabloda özetleyiniz.

Bilgiyi elde ettiğiniz kaynak	Canlının adı	Canlıya ait yapı ve bu yapının özelliği	Yapının işlevi	Bu işlevin canlıya sağladığı yararlar	Bu yapının özelliğini kullanarak insanların hangi problemini çözebilirsiniz?

EK 3

Hayali Canlının Adaptasyonları

Takımınızın Adı: ……

Takım arkadaşlarınızla birlikte hayali bir canlı düşünün. Hayali canlının sahip olacağı özelliklere karar verirken her birinizin birinci aşamada bilgi sahibi olduğu farklı canlılara ait yapılar ve bu yapıların işlevlerini kullanabilirsiniz. Hayali canlınız için seçtiğiniz yapıları, yapıların işlevlerini ve canlıya sağladığı yararları aşağıdaki tabloyu kullanarak açıklayınız.

Açıklamalar / Yapılar	Yapının adı ve özelliği (Kanat, kuyruk, ağız, dişler, kök, yaprak, hortum, göz, vb.)	Yapının işlevi	Neden bu yapıyı seçtiğinizi açıklayınız? (Bu yapı canlınızın hayatta kalması için ne tür bir yarar sağlayacak?)
Canlınız hangi dış yapılara sahip olacak?			
Canlınız hangi iç yapılara sahip olacak?			
Canlınız besinlerini bulmak ve yemek için hangi yapılara sahip olacak?			
Canlınız düşmanlarından korunmak için hangi yapılara sahip olacak?			
Canlınız arkadaşlarıyla ve yavrularıyla haberleşmek için hangi yapılara sahip olacak?			
Canlınız eş bulmak için hangi yapılara sahip olacak?			
Siz de ekleyebilirsiniz…			

EK 4

Hayali Canlının Çizimi ve Etiketlenmesi

Takımınızın Adı: ……

Hayal ettiğiniz canlının resmini çiziniz. Resminizi çizerken hayal ettiğiniz canlıya ait yapıları detaylı olarak göstermeye dikkat ediniz.
Canlımızın bilimsel adı: ----------
Canlınızı bilim dünyasına tanıtan bir hikâye ya da haber yazınız:
---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------

EK 5

Hayali Canlınızı Tanıtınız

Takımınızın Adı: ……

Hayali canlınızı bilim dünyasına tanıtacaksınız. Bunun için aşağıdaki tür künyesini oluşturacaksınız. Bu künyede genel olarak canlınızın sahip olduğu yapılar ve özellikleri; bu özellikleri dikkate alarak bilimsel olarak ait olduğu grup, yaşam alanı, yuvası, besin kaynakları, düşmanları vb. yer verebilirsiniz.

Canlımızın bilimsel adı: (İki isimden oluşan ikili isimlendirme adı verilen Latince bir isim olmalıdır. İlk isim *cinsi*, ikinci isim ise *tür* olarak tanımlanır. İsmin tamamı italik yazılmalıdır (ör., *Homo sapiens*) ve cins adının ilk harfi büyük büyük yazılarak kısaltılmalıdır (ör., *H. sapiens*).	
Canlımızın ait olduğu grup: Bitki-hayvan- mikroskobik canlı- mantar mı olduğunu belirtiniz. Bitki ise çiçekli/çiçeksiz hayvan ise omurgalı/omurgasız mı? Omurgalı canlı ise memeli-balık-kurbağa-sürüngen-kuş mu? Omurgasız canlı ise böcek-örümcek-solucan-salyangoz vb. mi? ya da birden çok gruba girebilir şeklinde özellikleriyle tanımlayınız.	
Canlımızın sahip olduğu vücut kısımları: (Kuyruk, kanat, hortum, ağız, gaga, yaprak, kök, bacaklar, kulaklar vb. şeklinde özellikleriyle tanımlayınız)	
Canlımızın yaşadığı yer: (Çöl/deniz/orman/kutuplar vb. şeklinde özellikleriyle tanımlayınız.)	
Canlımızın yuvası ve özellikleri:	
Canlımızın besin kaynağı:	
Canlımızı bekleyen tehlikeler:	
Canlımızın en güçlü özelliği:	
Canlımızın en zayıf özelliği:	

EK 6

Hayali Canlı Değerlendirme Rubriği

Takım Adı: ……

Boyut	Kriter	Hayali Canlı Değerlendirme Rubriği			
		0	1	2	3
Model geliştirme ve kullanma	Canlının adlandırılması ve sınıflandırılması	Canlı adlandırılmamış ve sınıflandırılmamıştır.	Canlı adlandırılmıştır fakat sınıflandırılmamıştır.	Canlı sınıflandırılmış fakat adlandırılmamıştır.	Canlı adlandırılmış ve sınıflandırılmıştır.
	Çizim ve etiketleme	Canlı çizilmemiştir.	Canlının çizimi net değildir ve ince detaylar eksiktir.	Canlının çizimi nettir fakat ince detaylar eksiktir.	Canlının çizimi nettir ve ince detaylara sahiptir.
	Betimleme	Canlı betimlenmemiştir.	Canlının betimlemesi ile çizim ile uyuşmuyor.	Canlının betimlemesi ile çizimi tam olarak uyuşmuyor.	Canlının betimlemesi ile çizimi ile uyuşuyor.
Yapı ve İşlev	Beslenme	Yapı ve işlev arasında bir ilişki yoktur.	Canlı modellenen yapılarıyla besin tüketemez.	Canlı modellenen yapılarıyla güçlükle besin tüketebilir.	Canlı modellenen yapılarıyla kolayca besin tüketebilir.
	Düşmanlardan korunma	Yapı ve işlev arasında bir ilişki yoktur.	Canlı modellenen yapılarıyla avcılarından korunamaz.	Canlı modellenen yapılarıyla avcılarından güçlükle korunabilir.	Canlı modellenen yapılarıyla avcılarından kolayca korunabilir.
	Haberleşme	Yapı ve işlev arasında bir ilişki yoktur.	Canlı modellenen yapılarıyla haberleşemez.	Canlı modellenen yapılarıyla güçlükle haberleşebilir.	Canlı modellenen yapılarıyla kolayca haberleşebilir
	Eş bulma	Yapı ve işlev arasında bir ilişki yoktur.	Canlı modellenen yapılarıyla eş bulamaz.	Canlı modellenen yapılarıyla güçlükle eş bulabilir.	Canlı modellenen yapılarıyla kolayca eş bulabilir.
	Yaşam alanı	Yapı ve işlev arasında bir ilişki yoktur.	Canlı modellenen yapılarıyla yaşam alanında hayatta kalamaz.	Canlı modellenen yapılarıyla yaşam alanında güçlükle hayatta kalabilir.	Canlı modellenen yapılarıyla yaşam alanında kolayca hayatta kalabilir.
Toplam Puan	…/24				

EK 7

Büyük Tasarım Görevi Taslak Çizim

Takımınızın Adı: ……

Üniteye başlarken size verilen büyük tasarım görevinizi tekrar okuyunuz. Bu aşamaya kadar öğrendiğiniz bilimsel bilgileri büyük tasarım göreviniz için uygulayacaksınız. Takımınızla birlikte oluşturacağınız tasarımınıza ilişkin olarak taslak çiziminizi aşağıya çizerek aşağıdaki soruları yanıtlayınız.

Tasarımınızı oluştururken hangi canlının yapı ve özelliğini kullandınız?

Tasarımınız insanların hangi sorununa nasıl çözüm üretecek?

Hangi malzemeleri tasarımınızın hangi bölümünde kullanacaksınız?

EK 8

Biyomimikri Tasarım Görevi Değerlendirme Rubriği

Mühendislik Tasarım Süreci	0	1	2	3
Problemin ya da İhtiyacın Tanımlanması	İhtiyaç/problem tanımlanmamış.	İhtiyaç/problem yüzeysel olarak tanımlanmış.	İhtiyaç/problem tanımlanmış.	İhtiyaç/problem tüm detaylarıyla açıkça tanımlanmış.
	Kriterler ve kısıtlamalar tanımlanmamış.	Kriter ve kısıtlamaların bir kısmı tanımlanmış.	Kriter ve kısıtlamaların çoğunluğunu tanımlanmış.	Kriterler ve kısıtlamaların tamamı tanımlanmış.
Problemin ya da İhtiyacın Araştırılması	İhtiyaç/problemin çözümüne yönelik gereksinim duyulan bilgi belirlenmemiş.	İhtiyaç/problemin çözümüne yönelik gereksinim duyulan bilginin bir kısmı belirlenmiş.	İhtiyaç/problemin çözümüne yönelik gereksinim duyulan bilginin çoğunluğu belirlenmiş.	İhtiyaç/problemin çözümüne yönelik gereksinim duyulan bilginin tamamı belirlenmiş.
	Elde edilen bilginin insanların ihtiyacını/problemlerini çözmek için nasıl kullanılacağı belirlenmemiş.	Elde edilen bilginin insanların ihtiyacını / problemlerini çözmek için nasıl kullanılacağı yüzeysel olarak belirlenmemiş.	Elde edilen bilginin insanların ihtiyacını/problemlerini çözmek için nasıl kullanılacağı belirlenmiş.	Elde edilen bilginin insanların ihtiyacını/problemlerini çözmek için nasıl kullanılacağı tüm detaylarıyla açıkça belirlenmemiş.
Olası Çözümlerin Geliştirilmesi	İhtiyaç/problemin giderilmesine yönelik çözüm önerisi sunulmamış.	İhtiyaç/problemin giderilmesine yönelik sunulan çözüm önerisi kriterler ve kısıtlamaların bir kısmı karşılanmış.	İhtiyaç/problemin giderilmesine yönelik sunulan çözüm önerisi kriterler ve kısıtlamaların çoğunluğu karşılanmış.	İhtiyaç/problemin giderilmesine yönelik sunulan çözüm önerisi kriterler ve kısıtlamaların tamamı eksiksiz karşılanmış.
	Çözüm önerisine yönelik taslak çizilmemiş.	Taslak çizim çözüm önerisini yüzeysel olarak yansıtmış.	Taslak çizim çözüm önerisini yansıtmış.	Taslak çizim çözüm önerisini tüm detaylarıyla yansıtmış.
En İyi Çözümlerin Seçilmesi	Çözüm önerilerinin olumlu ve olumsuz yönleri tanımlanmamış.	Çözüm önerilerinin olumlu ve olumsuz yönlerini yüzeysel olarak tanımlanmış.	Çözüm önerilerinin olumlu ve olumsuz yönlerini çoğunlukla tanımlanmış.	Çözüm önerilerinin olumlu ve olumsuz yönleri tam ve eksiksiz olarak tanımlanmış.
	Seçilen çözümün kriterleri ve kısıtlamaları karşılayıp karşılamadığı açıklanmamış.	Seçilen çözüm için gerekçelerin bir kısmı açıklanmış.	Seçilen çözüm için gerekçelerin çoğunluğu açıklanmış.	Seçilen çözüm için gerekçelerin tamamı detaylarıyla açıklanmış.
Prototip Oluşturulması	Çözüm önerisine yönelik bir model / prototip oluşturulmamış.	Çözüm önerisine yönelik kısmen uygun bir model / prototip oluşturulmuş.	Çözüm önerisine yönelik uygun bir model / prototip oluşturulmuş.	Çözüm önerisine yönelik tamamen uygun bir model/prototip oluşturulmuş.
	Model/ prototip için kriter ve kısıtlamaları karşılayan malzeme kullanılmamış.	Model/ prototip için kriter ve kısıtlamaları kısmen karşılayan malzeme kullanılmış.	Model/ prototip için kriter ve kısıtlamaların çoğunluğunu karşılayan malzeme kullanılmış.	Model/ prototip için kriter ve kısıtlamaların tamamını karşılayan malzeme kullanılmış.
Çözümlerin test edilmesi ve değerlendirilmesi	Model/ prototipin ihtiyacı/ problemi nasıl çözeceği test edilmemiş.	Model/ prototipin ihtiyacı / problemi nasıl çözeceği test edilmiş. Test sonuçları analiz edilmemiş.	Model/ prototipin ihtiyacı / problemi nasıl çözeceği test edilmiş. Test sonuçları kısmen analiz edilmiş.	Model/prototipin ihtiyacı/ problemi nasıl çözeceği test edilmiş. Test sonuçlarının tamamı analiz edilmiş.
	Test sonuçlarına ilişkin veriler bilimsel bir dil kullanılarak açıklanmamış.	Test sonuçlarına ilişkin verilerin bir kısmı bilimsel bir dil kullanılarak açıklanmış.	Test sonuçlarına ilişkin verilerin çoğunluğu bilimsel bir dil kullanılarak açıklanmış.	Test sonuçlarına ilişkin verilerin tamamı bilimsel bir dil kullanılarak detaylarıyla açıklanmış.
Çözümlerin Paylaşılması	Tasarımların ihtiyacı/ problemi nasıl çözeceği açıklanmamış.	Tasarımların ihtiyacı/ problemi nasıl çözeceği kısmen açıklanmış.	Tasarımların ihtiyacı/ problemi nasıl çözeceği açıklanmış.	Tasarımların ihtiyacı/ problemi nasıl çözeceği tam ve eksiksiz açıklanmış.
	Canlı/canlılara ait yapı/yapılar ve bu yapıların fonksiyonlarından ne şekilde yararlanıldığı belirtilmemiş.	Canlı/canlılara ait yapı/yapılar ve bu yapıların fonksiyonlarından ne şekilde yararlanıldığı kısmen belirtilmiş.	Canlı/canlılara ait yapı/yapılar ve bu yapıların fonksiyonlarından ne şekilde yararlanıldığı belirtilmiş.	Canlı/canlılara ait yapı/yapılar ve bu yapıların fonksiyonlarından ne şekilde yararlanıldığı tam ve detaylarıyla belirtilmiş.
Yeniden Tasarım	Tasarım için gerekli iyileştirmeler tanımlanmamış.	Tasarım için gerekli iyileştirmeler kısmen tanımlanmış.	Tasarım için gerekli iyileştirmeler tanımlanmış.	Tasarım için gerekli iyileştirmeler detaylarıyla tanımlanmış.
	Çözümlerin test edilmesi ve paylaşılması sonucunda elde edilen veriler ve geri bildirimler doğrultusunda tasarımlar iyileştirilmemiş.	Çözümlerin test edilmesi ve paylaşılması sonucunda elde edilen veriler ve geri bildirimler doğrultusunda tasarımlar kısmen iyileştirilmiş.	Çözümlerin test edilmesi ve paylaşılması sonucunda elde edilen veriler ve geri bildirimler doğrultusunda tasarımlar iyileştirilmiş.	Çözümlerin test edilmesi ve paylaşılması sonucunda elde edilen veriler ve geri bildirimler doğrultusunda tasarımlar en iyi şekilde iyileştirilmiş.
Toplam Puan	…/48			

EK 9

Biyomimikri STEM Etkinliği Öğrenci Yansıtıcı Değerlendirme Formu

Aşağıdaki soruları boşluklara cevaplayınız. Açıklamak için çizim ekleyebilirsiniz. Bunun için kâğıdın arka yüzünü veya ayrı bir kâğıt kullanabilirsiniz.

1. Modelinizi/prototipinizi tasarlarken ne tür zorluklarla karşılaştınız?

.....

.....

2. Bu zorlukların üstesinden nasıl geldiniz?

.....

.....

3. Çalışmada neler öğrendiniz?

.....

.....

4. Modelinizi/prototipinizi iyileştirmek için neler yaptınız?

.....

.....

5. Bu çalışmada neleri sevdiniz?

.....

.....

6. Bu çalışmada neleri sevmediniz?

.....

.....

7. Bir takım olarak nasıl çalıştığınızı açıklayınız?

.....

.....

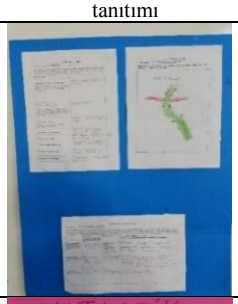
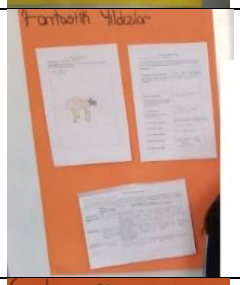
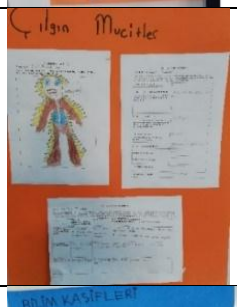
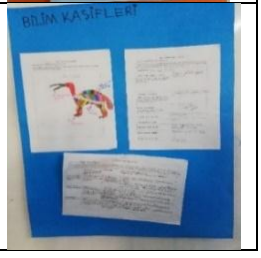
8. Bu çalışmada neleri değiştirmek isterdiniz?

.....

.....

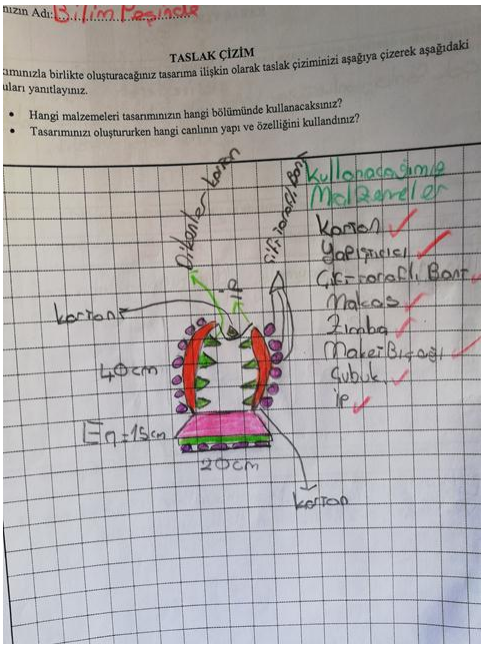
EK 10

Çizimler ve Oluşturulan Hayali Canlılar

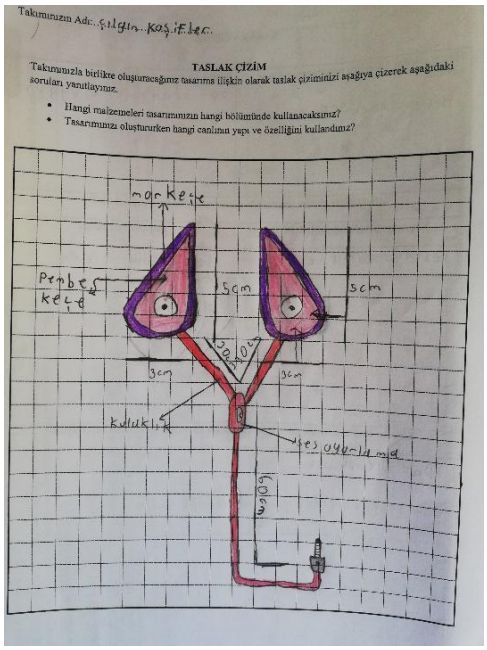
	Hayali organizmanın tanıtılması	Hayali organizmanın modellenmesi	Hayali organizmanın tanıtımı
Takım 1	Uçan sürüngen sürüngenler ve kuşlar sınıfındadır. Kuyruğu, kanatları, ağzı ve bacakları vardır. Yağmur ormanlarında yaşar, çalılıklara yuva yapar, yerde sürünür ve uçabilir. Geko'nun ayakları gibi yapışkan ayakları vardır. Beslenmek için avlanır. En güçlü özellikleri zehirli dikenleri ve gözleri, avcılarından korunmasına yardımcı olur. En zayıf özelliği yavaş yürümesidir. Hassas kulaklarla duyabilir ve uluyarak iletişim kurabilir. Güzel gözleri, ağzı ve yuva yapabilmeleri, uçan sürüngenin eş bulmasına yardımcı olabilir.		
Takım 2	Aslan başlı çita memeliler sınıfındadır. Kuyruğu, ağzı, burnu, kulakları ve bacakları vardır. Kendini sıcak tutmak için kürkü ve nefes almak için akciğerleri vardır. Çölde yaşar, ağaçların üzerinde yuva yapar ve beslenmek için avlanır. Avlanmak ve avcılarından korunmak için en güçlü özellikleri keskin dişleri, pençeleri ve bacaklarıdır. En büyük tehlike onlar için insandır. Koku alma kabiliyeti ile iletişim kurar. Bu yetenek ve bir eş bulmasına da yardım eder.		
Takım 3	Yumurtlayan memeli Babacan'ın kuyruğu, ağzı, boynuzu, dişleri, pençeleri, kulakları ve kara benekleri vardır. Kalın kemikli bir omurgalıdır. Kıllı bir vücuda ve yırtıcı hayvanlardan korumaya yardımcı olan kalın bir yağ tabakasına sahiptir. Babacan ormanda yaşar ve tepenin üzerindeki bir mağaraya yuvasını yapar. Balık ve et yer. Avcılar ve kendi türü Babacan'ın hayatı için tehlikelidir. Babacan'ın en güçlü yapıları zehirli dişleriyken, uzun kuyrukları olan kamuflaj ve boynuzları en zayıf yapılarıdır. Göz alıcı renklere ve renk değiştirme özelliklerine sahip olmak Babacan'ın eş bulmasını sağlar.		
Takım 4	Ulti-ayı iki yaşamlıdır. Ağzı, ciğerleri, solungaçları, kulakları, bacakları, dişleri, pençeleri ve gözleri vardır. Ciğerleri ve solungaçları sayesinde denizde ve karada nefes alabilir. Etçildir ve ormanda yaşar. Avcısı şahindir. Pençeleri ve dişleri savunmaya yardımcı olur. Kalın kürk, onu soğuk havalardan uzak tutmaya yardımcı olur. Daha güçlü olan kısmı Geko gözleridir. Bu sayede her şeyi görebilir. En zayıf özelliği korkak olmasıdır. Güzel bir sese sahip olması eş bulmasına yardımcı olur.		
Takım 5	Tekakdomeji sürüngen ve etoburdur. Daha iyi görmek ve avlamak için büyük gözleri vardır ve keskin dişleriyle avını parçalar. Avcılarından korunmak için büyük bir kabuğu vardır. Tekakdomeji ormanda ağaç kovuğunun içinde yaşar. Tekakdomeji'nin en güçlü yapısı zehirli dikenleridir, en zayıf yapısı da ayak tırnaklarıdır. Zehirli dikenler yaşamını korumasına yardımcı olur. Ayrıca, uzun bacakları sayesinde hızlı koşabilir. Tekakdomeji iletişim için kurt gibi ulur. İlginç görüşüyle ile kolayca bir eş bulabilir.		
Takım 6	Kızıl kafa, birden fazla grupta sınıflandırılabilir. Ormanda yaşar ve serin bir yerde yuvasını yapar. Kurt gibi pençeleri ve avlanmak için yarasa gibi zehirli dişleri vardır. Bukalemun gibi renk değiştirebilir ve kaplumbağa gibi güçlü kabuğu ve bir yılan gibi esnek omurgası vardır. En güçlü yapıları pençeleri ve zehirli dişlerdir, en zayıfı ise kuyruğudur. Balıkları avlarlar. Etçiller düşmanlarıdır. Kızıl Kafa, köpekler gibi havlayarak iletişim kurar. Süslü görünüşü sayesinde eş bulabilir.		

EK 11

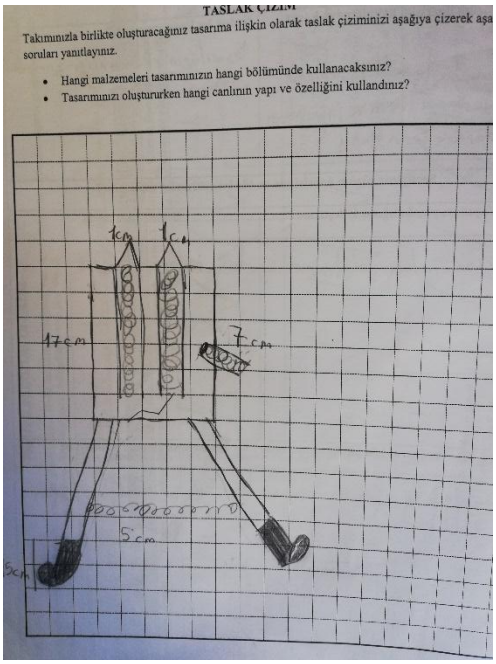
Büyük Tasarım Görevine Ait Taslak Çizimler



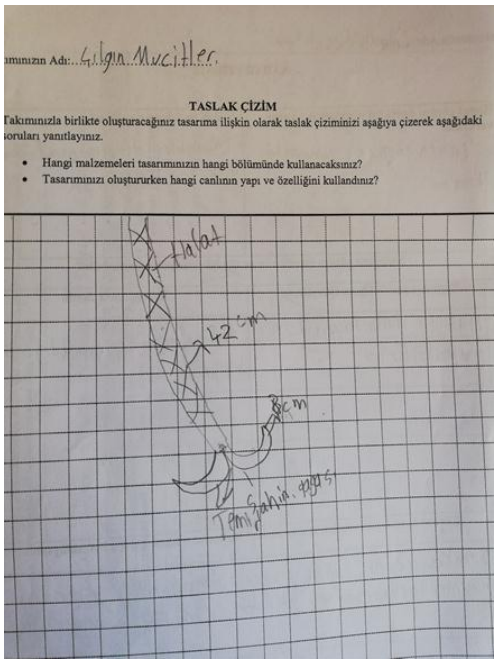
Takım 3
Tuzak Taslak Çizimi



Takım 4
Yarasa Kulağından Kulaklık Taslak Çizimi



Takım 5
Diker-Gömer Taslak Çizimi



Takım 5
Kanca Taslak Çizimi

EK 12

Geliştirilen Biyomimikri Modelleri

Takım	Model	Tasarımda kullanılan canlının adı	Canlıya ait yapı	Yapının fonksiyonu	Tasarımınız ne tür insan problemini çözdü?	Nasıl çalışıyor?	Tasarımınızın ne tür iyileştirmelere ihtiyacı var?
Takım 1 Balık yakalama filesi		Pelikan	Gaga	Geniş şekliyle balıkları yakalar.	İnsanlara balık avlamaları için yardım etmek	Sular delikler-den akar ve balıklar içeride kalır.	Su için boşaltma delikleri çok küçüktü. Daha büyük olması gerekiyor.
Takım 2 Kaymaz Çorap		Geko	Ayaklar	Düşmeden ve kaymadan tırmanır.	İnsanları kaymaktan ve düşmekten korumak.	Sürülen silikon kaymayı önler.	Çorap altındaki kaymaya dayanıklı malzeme kalındı. Daha ince olması gerekir.
Takım 3 Tuzak		Sinekkapan Bitkisi	Yaprak	Böcekleri ve sinekleri yakalar.	İnsanlara avlanmaları için yardım etmek.	Hayvanlar adımını tuzağa atınca yapraklar kapanır.	Modelin kenarını genişletmek gerekiyor.
Takım 4 Yarasa Kulağından Kulaklık		Yarasa	Kulak	Kulakları ile görür.	Duyamayan insanların duymalarını sağlamak. Ayrıca ses yalıtımı için kullanılabilir	Ses dalgalarını insan beynine gönderir.	Kulaklığın boyutu
Takım 5 Kanca		Şahin	Pençe	Avlarını avlar ve taşır.	İnsanlara ağır şeyleri taşımaları için yardım etmek.	Yük kancaya asılabilir ve insanlar yükü yüksekte tutarlar.	
Takım 6 Diker-Gömer		Tavuk	Gaga	Kavga etme ve korunma. Otları yolar ve çukur açar.	İnsanların kolayca tohum dikmelerini sağlamak.	Tavuğun gagasından biri deliği kazar, diğeri tohumu koyar ve deliği kapatır.	Bizim modelimizde gaga tavuk gagasına benzemiyordu