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The effect of STEM application on 21st-century skills of middle school students and student experiences

[1]Mehmet Yavuz , [2]Mehmet Hasançebi , and [3]Funda Yeşildağ Hasançebi

[1] IT Teacher, Ministry of Education, Diyarbakir
[2] Science Teacher, Ministry of Education, Giresun
[3] Science Education, Faculty of Education, Giresun University, Giresun

Corresponding author: Mehmet YAVUZ (yavuz.mehmet21@gmail.com)

ABSTRACT This study aims to reveal the effect of the STEM approach on 21st-century skills of middle school students and to determine their experiences about STEM. This application, which lasted 6 weeks with 7th-grade students, was realized with 35 students. In the study, by using the explanatory mixed-method, firstly, quantitative data was taken and qualitative data were tried to be explained. In the first stage of the study, the pre-test and post-test results were examined in the group by using a dependent group t-test. "Multidimensional 21st Century Skills Scale" was used as a pre-test and post-test tool. In the second stage of the study, student experiences for STEM applications were revealed using the semi-structured interview form, which is one of the qualitative data collection methods. In the findings of the study, it was seen in the results of the analysis that the STEM approach contributed positively to 21st-century skills. Besides, a significant difference was observed between the pre-test and post-test in five sub-dimensions in the scale. However, in the results of the interviews, it was stated that the students were enjoyable to study with STEM, increased communication within the group, and encouraged the student to research and think. It was also observed that some students had difficulties during the application, complained about the lack of time, and had difficulty in designing.

KEYWORDS: 21st Century Skills, Science, Semi-Structured Interview, STEM, Success.

1. INTRODUCTION

Rapidly advancing scientific and technological developments; has revealed the need to keep up with this development in individuals and communities. These needs bring some skills that people should have. These skills also called 21st-century skills are called problem-solving, critical thinking, collaboration, entrepreneurship, etc. [1]. There are different opinions about what 21st-century skills are in the literature. Learning and innovation skills (creativity, innovation, critical thinking, problem-solving, communication, collaboration), knowledge, media, and technology skills (information literacy, media literacy) and technology literacy and life-career skills (flexibility, adaptability, assertiveness, self-management, social and intercultural skills, productivity, responsibility, leadership) [2]. In addition to these, while seeing different skills in the literature, there is a common tendency of these skills. The 21st-century skills focused on this research are listed as "Information and Technology Literacy Skills", "Critical Thinking and Problem-Solving Skills", "Entrepreneurship and Innovation Skills", "Social Responsibility and Leadership Skills" and "Career Awareness".

The need to keep up with rapid changes in the 21st century brought innovations in the field of education. Depending on the needs of the current period, changes may occur in the content, goals, and form of education provided to individuals [3]. Countries that want to exist in global competition need

to keep up with innovative understanding. This has revealed the necessity to adapt the educational needs of individuals to these innovations [4]. Individuals who will form the workforce in the future must be competent in the fields of science, technology, engineering, and mathematics [5]. Many disciplines should be applied together to raise individuals with a new hundred years of skills [6]. Since STEM (Science, Technology, Engineering, and Mathematics) education approach also offers an interdisciplinary field of study, it has an important place in raising individuals with 21st-century skills [7]. STEM as an educational approach; In the United States, it aims to teach science, technology, mathematics, and engineering fields in connection with each other at all levels of education [8-9].

When the literature is examined, research on the integration of 21st-century skills with technology, specific lessons/subjects (egg environmental science), skills (critical thinking, creativity, etc.) or curriculums stands out [10-12]. In the national literature, the pre-service teachers' 21st century determining their skills [13], determining the technology, tools, or methods that affect the 21st-century skills of their students [14-16] and how 21st-century skills are defined and There are researches to explain the classification [16-18]. Regarding the effect of STEM on skills, teachers and prospective teachers generally gain 21st-century skills [19-20] and scientific process skills [21-22]. Its effect has been investigated. However, STEM s students in the 21st century. Investigating the effect of gaining skills will contribute to the literature.

STEM education covers skills in science, technology, and mathematics. This education has two main purposes [23]. The first is employment, and the second is to train students with competencies in these fields. When the literature is examined, STEM applications; rather than being context-based and problem-solving-oriented, it has been observed that it is addressed towards the ability to produce and use technology [24]. STEM approach is stated to be evidence-based and problem-solving based [25]. Besides, establishing a relationship with daily life, which is the basis of the constructivist approach, is one of the results provided by the STEM approach in students.

Individuals and societies should also keep pace with this differentiation towards the needs of a different world. STEM-related fields in Turkey, unfortunately, very few studies carried out that increasing the number of STEM-related studies in Turkey is of great importance [26]. Considering the studies in the literature in the last 5 years, it is seen that STEM education has become widespread at the secondary level. As of the 2017-2018 academic year in the updated curriculum in Turkey was inserted into the STEM education programs. This situation requires having some skills with it. In this context, STEM education aims to provide individuals with these skills. In this context, the opinions of students who personally experienced the STEM approach on the effect of this approach on 21st-century skills are important. The study aims to reveal the effect of 21st-century skills according to the opinions of middle school students studying with the STEM approach and to determine their experiences about STEM. In this context, research questions;

1. What is the effect of STEM approach on 21st-century skills according to the opinions of middle school students?

a. What impact does it have on information and technology literacy skills?

b. What is its effect on critical thinking and problem-solving skills?

c. What is the impact on entrepreneurship and innovation skills?

d. What effect does it have on social responsibility and leadership skills?

e. What is its effect on career awareness?

2. What are the experiences of secondary school students towards the STEM approach?

a. What are the difficulties encountered in the STEM approach according to the opinions of the secondary school students?

b. What are the positive aspects of the STEM approach according to the opinions of secondary school students?

2. METHOD

Since qualitative and quantitative data are used together in this study, a mixed research method was used. Mixed research; is a research approach in which the researcher integrates two sets of data, where he gathers both quantitative and qualitative data to understand research problems, and then draws out the advantages of integrating these two sets [27]. Qualitative and quantitative data must be supportive of each other in a strong mixed pattern study [28]. In the study, a descriptive mixed research design, which is one of the mixed research patterns in which qualitative data is collected [29] to explain the quantitative data, was used. For this reason, the study consists of two stages.

In the first stage, a longitudinal survey model from a quantitative research pattern was used. In longitudinal survey studies, repeated measurements are made at different times to examine the variations of the research variables based on time [30]. With this technique, in the seventh-grade science course, the "Interaction of Light with Matter" unit was handled with a STEM approach for six weeks. Quantitative data were obtained by applying “Multidimensional 21st Century Skills Scale” to these students as a pre-test and a post-test at the end of the practice. In the second stage of the study, interview technique, one of the qualitative data collection types, was used. The most frequently used interview in qualitative research is a mutual and interactive form of communication-based on a predetermined and preferred way of asking and answering questions [31]. In this context, after six weeks of STEM application, the interview technique was used with volunteer students.

2.1 PARTICIPANTS

The study 7th grade students in the 2019-2020 academic year in a secondary school district in the north of Turkey participated. The sample of the study consists of 35 students, 20 males, and 15 female students.

2.2 APPLICATION PROCESS

The application in the "Interaction of Light with Matter" unit of the 7th-grade science course took six weeks in total. STEM activity papers were distributed to the students. During the process, they were asked to design engineering that solved a problem situation related to each subject. Classes were divided into seven groups of five students, and activities were conducted in the form of group work. The problem situation was presented through a story in STEM activity papers distributed to students at the beginning of each subject. While searching for a solution proposal for the problem situation, students were provided to learn the concepts related to the subject. Then students were asked to make their designs as a group in the lesson. After all the groups completed their designs, each group explained their design and explained to their classmates how they came up with a solution. Below are the activity and the gains related to the subject held every week.

Table 1. Activities and subject gains

Week	Activities	Gains
1.	Designing a sweater that suits every environment	She discovers that light can be absorbed by matter as a result of interaction with matter.
2.	Designing a color wheel	It concludes that white light is a combination of all light colors.
3.	Designing a solar panel	It gives examples of innovative applications of solar energy in daily life and technology. Discusses the ideas about how solar energy will be used in the future.
4.	Designing a periscope	Observes the mirror types and gives examples of usage areas.
5.	Designing a stove with a hollow mirror	Compares the images formed in flat, pit, and hump mirrors.
6.	Designing a telescope	Determines the focal points of thin and thick-edged lenses by experimenting. It gives examples of the usage areas of lenses in daily life and technology.

Below are some products that students in the application process have produced.

Figure 1. Products of students who carry out the application

2.3 COLLECTION OF DATA

In the first stage of the research, “Multidimensional 21st-century skills scale” developed by [32] was used. The scale developed in the 5-point Likert type; consists of a total of five sections: Information and Technology Literacy Skills, Critical Thinking and Problem-Solving Skills, Entrepreneurship and Innovation Skills, Social Responsibility and Leadership Skills, and Career Awareness. The answer options of the items in the scale were arranged as "5 = I totally agree", "4 = I agree", "3 = I have no idea", "2 = I do not agree" and "1 = I strongly disagree". This scale prepared for 21st-century skills of students consists of 41 items in total. The Cronbach's Alpha reliability score of the scale is 0.86. The scale was applied to the same study group twice in total as pre-test and post-test. In the second stage of the study, the interview form was used as a data collection tool. This form was applied to 12 students who wanted to participate in the interview voluntarily among the students who participated in the STEM application. The questions used in the form are as follows.

1. What are the shortcomings of the STEM application you think (What are the points you see as a disadvantage)

2. What are the pros of STEM application applied in your opinion? (What are the points you see as an advantage)

2.4 DATA ANALYSIS

The analysis stage of the study consists of two stages, quantitative and qualitative analysis.

a) QUANTITATIVE ANALYSIS

The data obtained from the scale were entered SPSS 23 program before and after the application. A dependent group t-test was used to evaluate the group internally, that is, to learn the effect of STEM approach on 21st-century skills. Data were tested at $p < .05$ significance level.

b) QUALITATIVE ANALYSIS

After six weeks of STEM application, students were interviewed. Voluntarily, a semi-structured interview was held with the students in the group. Voice recording was taken during the interview. Based on volunteering, the data of the 12 students who participated in the interview were listened to by the researchers and transferred to the computer environment. Conversation recordings are added directly to the Microsoft Word program without making any changes in the transfer process. All structured interview records were collected one after the other and interesting statements were determined and the codes of the study were drawn. Later, the authors grouped these codes to be related to each other and created the categories. The last relevant categories are grouped and themes are created.

3. FINDINGS

In this section, the findings related to the results of the analysis carried out to determine whether the STEM application differs from the 21st-century skills in terms of Information and Technology Literacy

Skills, Critical Thinking and Problem-Solving Skills, Entrepreneurship and Innovation Skills, Social Responsibility and Leadership Skills and Career Awareness. It was evaluated.

3.1 THE EFFECT OF STEM APPROACH ON 21ST CENTURY SKILLS

Dependent groups t-test was used to determine whether seventh-grade students who taught science lessons with the STEM approach differ significantly according to 21st-century skills variables. The results of the students' pretest and posttest are presented in Table 2.

Table 2. Dependent groups t-test results of the 21st-century skills scale

		N	*X*	*ss*	*Sd*	*t*	*p*
21st Century Skills Scale	Pre-Test	35	2.999	.188	34	-19.66	**.00**
	Post-Test	35	3.878	.282			

A statistically significant difference was observed between the pretest scores of students (X = 2.999, S = 0.188) and posttest scores (X = 3.878, S = 0.282) in favor of the posttest [t (34) = -19.66, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' 21st-century skills. The dependent group t-test scores of these scores were calculated to determine whether there were significant differences in the five sub-dimensions included in the 21st-century skills scale used. The results of these dimensions are given below as separate tables.

Table 3. Dependent groups t-test results related to information and technology literacy skills

		N	*X*	*ss*	*Sd*	*t*	*p*
Information and Technology Literacy Skills	Pre-Test	35	3.099	.307	34	-14.88	**.00**
	Post-Test	35	3.975	.201			

A statistically significant difference was observed between the pre-test scores (X = 3.099, S = 0.307) and the post-test scores (X = 3.975, S = 0.201) in favor of the post-test [t (34) = -14.88, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Information and Technology Literacy skills. Dependent groups t-test results of "Critical Thinking and Problem Solving" skills, another dimension of the scale, are given in Table 4.

Table 4. Dependent groups t-test results related to critical thinking and problem-solving skills

		N	*X*	*ss*	*Sd*	*t*	*p*
Critical Thinking and Problem Solving Skills	Ön Test	35	2.023	.291	34	-20.38	**.00**
	Son Test	35	4.047	.423			

A statistically significant difference was observed between the pre-test scores (X = 2.023, S = 0.291) and the post-test scores (X = 4.047, S = 0.423) in favor of the post-test [t (34) = -20.38, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Critical Thinking and Problem-Solving Skills. Dependent groups t-test results of "Entrepreneurship and Innovation" skills, one of the other dimensions of the scale, areas in Table 5.

Table 5. Dependent groups t-test results for entrepreneurship and innovation skills

		N	*X*	*ss*	*sd*	*t*	*p*
Entrepreneurship and Innovation Skills	Pre-Test	35	2.714	.257	34	-10.25	.00
	Post-Test	35	3.617	.395			

A statistically significant difference was observed between the pre-test scores (X = 2.714, S = 0.257) and the post-test scores (X = 3.617, S = 0.395) in favor of the post-test [t (34) = -10.25, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Entrepreneurship and Innovation skills. Dependent groups t-test results of "Social Responsibility and Leadership" skills, one of the dimensions of the scale, are given in Table 6.

Table 6. Dependent groups t-test results related to social responsibility and leadership skills

		N	*X*	*ss*	*sd*	*t*	*P*
Social Responsibility and Leadership Skills	Pre-Test	35	3.350	.575	34	-3.33	**.002**
	Post-Test	35	3.742	.505			

A statistically significant difference was observed between the pre-test scores (X = 3.350, S = 0.575) and post-test scores (X = 3.742, S = 0.505) in favor of the post-test [t (34) = -3.33, p = 0.002]. This finding shows that the STEM approach used has a significant effect on students' "Social Responsibility and Leadership" skills. Dependent groups t-test results of "Career Awareness" skills, one of the dimensions of the scale, are given in Table 7.

Table 7. Dependent groups t-test results related to career awareness

		N	*X*	*ss*	*sd*	*t*	*P*
Career Awareness	Pre-Test	35	3.809	.581	34	-2.20	**.035**
	Post-Test	35	4.009	.361			

A significant difference was observed between the pre-test scores (X = 3.809, S = 0.581) and post-test scores (X = 4.009, S = 0.361) of students [t (34) = -2.20, p = 0.035]. This finding shows that the STEM approach used has a significant effect on students' Career Awareness skills.

3.2 STUDENTS' EXPERIENCES ABOUT STEM APPROACH

This section includes qualitative findings obtained as a result of a semi-structured interview. Here, the interview records of the students about their STEM activities were analyzed and the themes, categories, and codes formed as a result of the analysis are presented in Table 8.

Table 8. Theme, category and code information of qualitative data

Theme	**Category**	**Code**	**f**	**Example Student Discourses**
The advantages of STEM activities	21st-century skills	Career Consciousness (Feeling like an Engineer)	2	*S3: I felt like an engineer.* *S10: I always thought I was an engineer while researching and designing.*
		Critical thinking and problem solving	7	*S11: I like to think with my friends to solve the problem given by our teacher. I couldn't get used to it, but then I started to like it.* *S12: When I came to class, I was talking to my friends this time about how the teacher would present a problem. We were curiously waiting.*
		Communication and collaboration (belonging	5	*S2: It was so much fun working with the group. We did not want to breathe*

		to the group and communication)		*S4: I'm bored when the activities force. But my teacher and group friends helped. We did this job easier with the group*
		Entrepreneurship and innovation	3	*Q5: We were also designing in technology design lesson, but the designs in science lesson were useful* *Q10: We were researching and deciding which design to make*
		Information and technology literacy (Knowledge transfer-research)	8	*S3: It was fun to use the information I learned and researched* *S8: We researched on the internet in the parts we had difficulty*
	Learning Environment	Fun lesson	6	*S10: I didn't get used to it at first, but then it was fun.* *S7: The lesson was very enjoyable. Time has passed like water.*
		Positive attitude towards science	6	*S6: With this application, my interest in the course has increased. I don't understand how time passes. Everything was perfect.* *S9: Although I got used to it in the first place, I liked it later. We should even use it in other lessons. I will ask my math teacher to use STEM.*
The difficulties encountered	Time-consuming Events	Insufficient time	7	*S5: Time was not enough. We need extra time. Sometimes we even designed during recess.* *S5: Activities take a lot of time. I had a little difficulty.*
		Practice problem	4	*S7: I had a hard time using this activity for the first time.* *S9: Although I got used to it in the first place, I liked it later*
	Compelling Designs	Design challenge	5	*S2: But sometimes it was when we had a hard time making designs.* *S8: We used the internet when we had difficulty in design.* *S7: It has forced me to combine different designs.* *S1: I had difficulty in designing.*

When the students' views about the process were taken into consideration, the first theme was about the advantages of the activities. Under this theme, 21st-century skills and learning environment categories are included. These findings were determined that STEM activities contributed to students gaining 21st-century skills. Besides, these activities were found to make the learning environment more enjoyable and to provide students with a positive attitude towards science. In the second theme, students are faced with difficulties regarding STEM activities. The students stated that they had difficulty in completing the activities related to this process in time and design.

4. RESULT AND DISCUSSION

21st-century skills are embedded in new curricula with programs updated by MEB. For this purpose, the STEM approach is important. When the research results are examined, it was revealed that STEM activities positively affected the 21st-century skills of middle school students. When each sub-dimension of the 21st-century skills was examined separately, it was determined that there was a significant difference between the pre-test results of the students in all sub-dimensions in favor of the post-test. This result can be said that STEM activities increase students' information and technology literacy, critical thinking and problem-solving skills, entrepreneurship and innovation skills, social responsibility and leadership skills, and career awareness. When student discourses are examined, it is seen that it supports these results. The students stated that STEM activities developed critical thinking and problem-solving skills, strengthened the cooperation and communication aspects of the group, they felt like engineers during the activities, this process enabled them to make various designs, and they gained information and technology literacy by developing research and transferring information. We can explain this result as follows: During STEM activities, students encounter a problem situation in each activity and seek solutions for it. Acquiring this skill is essential. Because of the person; He can

use his many skills such as creativity, critical thinking, and cooperative work when he takes action to solve a problem situation [26]. In this process, the student begins to actively think about the problem he faces while looking for a solution and conducts critical thinking by conducting research inquiry at every stage of the process (research, proposing a solution, designing, etc.). While doing these, working with group friends develops students' cooperation and communication. It needs a variety of researches, both while proposing a solution to the problem and at the design stage, which enables them to transfer research and the information they acquire using technology. Because STEM education aims to use individuals' knowledge and skills with practical applications and to integrate them with daily life problems [33]. The process also offers students the opportunity to design. As a result of these design studies, students realize that the information they have when they reach a product works and wants to have more information [34]. However, these designs are effective in structuring scientific knowledge, creating a potential for students, and serving as a bridge for science learning [35]. Many studies in the literature emphasize that STEM education is the most appropriate approach to improve 21st-century skills [36-38].

Researches related to STEM and 21st-century skills were generally conducted with teachers and prospective teachers, and STEM activities were effective in gaining many 21st century skills of teachers and prospective teachers [19,20,40] and science teachers. He determined that there is a moderate positive relationship between 21st-century skills competence perceptions and attitudes towards STEM [41]. He argues that after the research they conducted with 7th-grade students, many skills aimed at individuals in the 21st century can be gained with STEM education [42]. When the effect of STEM activities on students is analyzed, it increases the academic success [43-45], in which students improved their scientific process skills [34], and their creative thinking skills [46] and it is emphasized that they have gained a positive attitude towards STEM [42,45].

At the end of the research, students stated that STEM activities make the learning environment more enjoyable and positively affect their attitudes towards science. Similarly, they stated that STEM positively improves middle school 5th-grade students' attitudes towards science and explained that this is because students make mini designs and obtain a product [47]. STEM applications increase students' interest in science subjects and their desire to learn [48]. However, another finding obtained in the research is that students have difficulty in raising and designing time during STEM activities. Since the process of researching and designing is unfamiliar with the students, and extra material, equipment, computer, internet, etc. for the learning environment may be due to the need. To prevent or minimize the time loss that may occur during the lesson, it is necessary to arrange the learning environment in advance, to have the necessary technological equipment and the necessary infrastructure ready for use, to check in advance, to determine the layout of the groups and to have the materials to be used ready

[42]. Besides, the application of STEM activities from time to time during the education period may help these students to overcome these difficulties.

As a result, STEM activities develop 21st-century skills of secondary school students. Because STEM activities by nature require many skills such as research, using technology, working with a group, creating products, and making presentations, and therefore students have the opportunity to develop these skills in learning environments where this approach is frequently used [42]. Besides, STEM practices contribute to the positive attitude of students towards learning science and to make the learning environment more fun. However, according to the opinions of the students who experience this STEM approach, it is determined that there may be difficulties during the process of raising and designing time in this process, and it is foreseen that these difficulties can be overcome with the plans and precautions taken before the implementation.

In future research, 21st-century skills can be handled separately, the effects of STEM applications (eg Argumentation supported STEM, Problem-based or project-based STEM applications) integrated with different methods on 21st-century skills can be investigated and these skills can be investigated with each other and other components of the learning environment their relationship can be examined. Besides, teachers who want to practice STEM in their classrooms; It is recommended that they behave meticulously in time planning and do not ignore the importance of doing STEM activities in improving students' skills.

5. REFERENCES

[1] National Research Council. (2011). *Successful STEM education: A workshop summary*. Washington, DC: National Academies Press.

[2] Partnership for 21st Century Skills-P21. (2009). *P21 framework definitions*. Retrieved from http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf. Date of Access: 03/05/2020.

[3] Aydemir, E, Kaysi, F, Gülsecen, S. (2019). Estimation of Turkish Language Exam Results of University Students According to Exam Preparation Levels. *Alphanumeric Journal, 7* (2), 351-356.

[4] Kaysi, F., & Aydemir, E. (2017). Evaluation of Interaction Dimensions in Distance Education Processes. *Journal of Social Sciences, 4* (11): 1-10.

[5] Organisation for Economic Co-operation and Development (OECD). (2017). PISA 2015 collaborative problem-solving framework. Paris: OECD Publishing. https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Collaborative%20Problem%20Solving%20Framework%20.pdf. Date of access: 10/05/2020.

[6] Yildirim, B (2018). Mus Alparslan University STEM Education Report - STEM Education for the Goals of 2023, 2053, and 2071. www.alparslan.edu.tr//IcerikDosya?link=2f9aeaf8ecf00870f840c297c8649b19518d6f0b. Date of Access: 01/05/2020.

[7] Roberts, A. (2012). A justification for STEM education. *Technology and engineering teacher, 71*(8), 1-4.

[8] Bybee, R. W. (2011). "Scientific And Engineering Practices In K-12 Classrooms: Understanding "A Framework For K-12 Science Education". *Science and Children, 49*(4), 10-16.

[9] MEB (Ministry of National Education) (2016). STEM education report. Ankara: Ministry of National Education, General Directorate of Innovation and Educational Technologies (YEGITEK).

[10] Afandi, A., Sajidan, S., Akhyar, M., & Suryani, N. (2018). Pre-Service Science Teachers' Perception About High Order Thinking Skills (HOTS) in the 21st Century. *International Journal of Pedagogy and Teacher Education, 2*(1), 107–114.

[11] Halverson, A. (2018). *21st-century skills and the "4Cs" in the English language classroom*. Retrieved from http://hdl.handle.net/1794/23598. Date of Access: 09/05/2020.

[12] Louis, R. C. (2012). *A case study exploring technology integration and incorporation of 21st-century skills in elementary classrooms.* College of Professional Studies Northeastern University, Boston, Massachusetts.

[13] Gunuc, S., Odabasi, H. F., & Kuzu, A. (2013). Defining 21st Century Student Features by Prospective Teachers: A Twitter Application. *Journal Of Theory & Practice In Education (Jtpe), 9*(4).

[14] Gulen, B. (2013). *Investigation of Secondary School Students' 21st Century Learning Skills and Information Technologies and Support Levels According to Gender and Grade Level.* Unpublished Master's Thesis, Gazi University Institute of Educational Sciences, Ankara.

[15] Kotluk, N., & Kocakaya, S. (2015) Digital stories in the development of 21st-century skills: Investigation of secondary school students' views. *Journal of Education and Teaching Research, 4*(2), 354-363.

[16] Yalcin, S. (2018). 21st-century skills and tools and approaches used to measure these skills. *Journal of Ankara University Faculty of Educational Sciences, 51*(1), 183-201.

[17] Ekici, G., Abide, O. F., Canbolat, Y., & Ozturk, A. (2017). Analysis of data sources for 21st-century skills. *Journal of Research in Education and Teaching., 6*(1), 1-12.

[18] Murat, A. (2018). *Examination of science teacher candidates' 21st-century skills competence perceptions and their attitudes towards STEM*. Unpublished Master Thesis. Firat University, Elazig.

[19] Deveci, I. (2018). Entrepreneurial Traits of STEM Awareness of Science Teacher Candidates. *Kastamonu Education Journal, 26*(4), 1247-1256.

[20] Eroglu, S., & Bektas, O. (2016). Views of STEM Education Science Teachers About STEM-Based Course Activities. *Journal of Qualitative Research in Education 4*(3), 43-67.

[21] Gokbayrak, S., & Karisan, D. (2017). Investigation of Sixth Grade Students' Opinions About STEM Based Activities. *Journal of Field Education Research, 3* (1), 25-40.

[22] Tarkin-Celikkiran, A., & Aydin-Gunbatar, S. (2017). Examination of the opinions of chemistry teacher candidates about STEM applications. *Yuzuncu Yil University Journal of Education, 14*(1), 1624-1656.

[23] Thomasian, J. (2011). Building a science, technology, engineering, and math education agenda: An update of state actions. Washington, DC: National Governors Association (NGA), Center for Best Practices. Retrieved from http://www.nga.org/files/live/sites/NGA/files/ pdf/1112STEMGUIDE.pdf. Date of Access: 08/05/2020.

[24] Bati, K., Caliskan, I., & Yetisir, M. I. (2017). Computational thinking and integrated areas approach in science education (STEAM). *Pamukkale University Journal of Education, 41*, 91-103.

[25] Freeman, S., Eddy, SL., McDonough, M., Smith, MK., Okoroafor, N., Jordt, H., & Wenderoth MP.(2014). *Active learning increases student performance in science, engineering, and mathematics.* Proc Natl Acad Sci USA 111, 8410–8415.

[26] Akgunduz, D., Ertepinar, H., Ger, A. M., Kaplan Sayi, A., & Turk, Z. (2015). STEM education workshop report: a comprehensive assessment of Turkey STEM education: Istanbul Aydin University STEM Center and Education.

[27] Creswell, J. W. (2019). *Introduction to mixed-method researches*, 2nd Edition.. (Ed., M. Sözbilir) Pegem Academy.

[28] Tashakkori, A., & Creswell, J. W. (2007). Exploring the nature of research questions in mixed methods research. *Journal of Mixed Methods Research, 1*(3), 207-211.

[29] Creswell, J. W., & Clark, V. L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

[30] Buyukozturk, S., Cakmak, E., Akgun, O. E., Karadeniz, S., & Demirel, F. (2018). *Academic research methods in education (25. Edition).* Pegem Academy, Ankara.

[31] Stewart, C. J., & Cash Jr, W. B. (1985). *Interviewing: Principles and practices*. Dubuque, IA: Wm. C.

[32] Cevik, M. & Senturk C. (2019). Multidimensional 21st-century skills scale: Validity and reliability study. *Cypriot Journal of Educational Sciences. 14*(1), 011–028.

[33] Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1–13.

[34] Yamak, H., Bulut, N., & Dundar, S. (2014). 5. The Effect of STEM Activities on the Scientific Process Skills and Attitudes of Science to Grade 5 Students. *Gazi University Journal of Gazi Education Faculty, 34*(2), 249-265.

[35] Fortus, D., Dershimer, R. C., Krajcik, J. S., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

[36] Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*, 30-35.

[37] Ejiwale, J. A. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education: Innovations and Research, 13*(3), 87.

[38] Ostler, E. (2012). 21st century STEM education: A tactical model for long-range success. *International Journal of Applied Science and Technology, 2*(1), 28-33.

[40] Hacioglu, Y. (2017). *The Effects of Science, Technology, Engineering, and Mathematics (STEM) Education Based Activities on Pre-Service Science Teachers' Critical Thinking Skills.* Unpublished Master's Thesis, Gazi University, Institute of Educational Sciences, Ankara.

[41] Murat, M. (2018). *The effect of the flipped class model on fifth-grade students' 21st-century skills and scientific epistemological beliefs.* Unpublished Master Thesis. Mugla Sitki Kocaman University, Institute of Educational Sciences, Mugla.

[42] Ozcan, H. & Koca, E. (2019). The effect of teaching pressure issue with STEM approach on the academic achievement and attitudes of STEM students to 7th-grade students, *Education and Science, 44* (198), 201-227.

[43] Cevik, M. (2018). Impacts of the project-based (PBL) science, technology, engineering, and mathematics (STEM) education on academic achievement and career interests of vocational high school students. *Pegem Journal of Education and Training, 8*(2), 281-306.

[44] Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics, 113*(5), 215-226.

[45] Toma, R. B., & Greca, I. M. (2018). The effect of integrative STEM instruction on elementary students' attitudes toward science. Eurasia Journal of Mathematics, *Science and Technology Education, 14*(4), 1383-1395.

[46] Kakarndee, N., Kudthalang, N., & Jansawang, N. (2018). The integrated learning management using the STEM education for improve learning achievement and creativity in the topic of force and motion at the 9th-grade level. *AIP Conference Proceedings, 1923*(1), 030024.

[47] Moore, T.J., Stohlmann, M.S., Wang, H.-H., Tank, K.M., & Roehrig, G.H. (2013). Implementation and integration of engineering in K-12 STEM education. In J. Strobel, S. Purzer, & M. Cardella (Edt.), *Engineering in precollege settings: Research into practice.* Rotterdam, the Netherlands: Sense Publishers.

[48] Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: a case study of design-based learning in a science context. *Journal of Technology Education, 19*(2), 22-39.