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PHYSICS-CHEMISTRY PRESERVICE TEACHERS' OPINIONS ABOUT PREPARING AND IMPLEMENTATION OF STEM LESSON PLAN

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Abstract

The popularization of the STEM educational model has also brought along the need for well-trained teachers. In this model, it is aimed to understand examples in real world and solve related problems. Of course, this depends on the development of critical thinking, creative thinking, researching and experimental skills. For these reasons, the opinions of the Physics-Chemistry teacher candidates regarding the preparation and implementation of STEM lesson plans were investigated. For this purpose, the preservice teachers were asked to form real life-related, information-based problems covering the acquisitions included in the high school programs and then they were expected to turn these into STEM lesson plans. The study is a descriptive study, one of the qualitative research methods. The data was collected via the forms developed by the researchers and including open-ended questions and one-to-one interviews. The data obtained were analyzed according to the content analysis steps, which is one of the qualitative research methods. When the analysis results were examined, it was found that the preservice teachers had difficulty in forming real life-related, information-based problems covering the acquisitions included in the high school programs and integrating them with scientific knowledge and in the engineering integration of STEM implementations and finding materials.

Keywords – Physics preservice teacher, Chemistry preservice teacher, STEM lesson plan.

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1. Introduction

The model having gained acceptance in recent years as one of the most important reform movements in the educational area of countries and put forward with the aim of integrating the disciplines of science, technology, engineering and mathematics is the STEM education model (Marginson, Tytler, Freeman & Roberts, 2013; Fitzallen, 2015; Wagner, 2014; Bybee, 2010; National Academy of Engineering [NAE] and the National Research Council [NRC], 2009; National Research Council [NRC], 2012; Smith & Karr-Kidwell, 2000). Shaughnessy (2013) sees STEM education as solving problems related to mathematics, science concepts and procedures by combining appropriate engineering and technology concepts. Lawrenz, Gravemeijer and Stephan (2017) state that a strong understanding of STEM is the key to a successful future. Since scientific and technological developments have advanced extremely rapidly and taken societies under influence in social, economic and technical areas, there have also appeared new requirements in the field of education. One of the most important of these requirements is the well-trained human force. For this reason, the STEM education model, an integration of the disciplines of science, technology, engineering and mathematics, is becoming widespread in many countries as an education model and it was included among teaching programs in our country, too. In this model, it is aimed to understand examples in real world and solve problems related to these. Of course, this depends on the development of critical thinking, creative thinking, researching and experimental skills.

The STEM education model enables students to think in an integrated way in the context of science, technology, engineering and mathematics by facing situations in daily life and implement these thoughts in real life events (Thomas, 2014). The STEM learning environments are considered to have important influences on students' experiences, academic success levels and advanced thinking skills and entrepreneurship and communication skills (Lou, Shih, Diez & Tseng, 2011; Tsai, 2007; Wendell, Connolly, Wright, Jarvin, Rogers, Barnett et al., 2010). The STEM Taskforce Report (2014) adopts the opinion that the STEM education is more than the appropriate integration of four disciplines and expresses this opinion in the way that "real life covers problem-based learning".

In the 21st century, the importance of the areas of science, mathematics, technology and engineering and individuals' need for having the skills required by this century draw attention toward teachers giving education in these areas and emphasize the vital importance of preparing STEM-based lesson plans for teachers giving lessons in these areas. Carr and Strobel (2011) state that there is a need for schools performing problem-based, applied and inquiry-based activities, which are able to integrate the contents of mathematics and science meaningfully. Moreover, it is stated that taking in hand the engineering design processes as a part of the secondary school curriculum will develop students' understanding of basic concepts and principles of a discipline and problem-solving abilities considerably (Diefes-Dux, Zawojewski & Hjalmarson, 2010; English & Mousdeoulis, 2011; Stoner, Stuby & Szczepanski, 2013). For this reason, teachers are very important in terms of developing the STEM skills at schools and achieving inter-disciplinary integration and it is important that teachers should receive training on STEM (Capobianco, 2013; Han, Yalvaç, Capraro & Capraro, 2015). Many studies draw attention to the importance of teacher education for STEM education. Capobianco (2013) carried out a two-week intensive education program for the preservice teachers and found that their skills of using engineering design process in the classroom developed. Han et al. (2015) suggest teachers take the STEM education based on effective project-based learning. Moreover, Hsu, Purzer and Cardella, (2011) suggest teachers become more acquainted with these concepts and use professional development programs in order to increase their motivation to implement these. Altan and Ercan (2016) drew attention to the finding that the STEM-based education intended for the science preservice teachers developed their STEM-based lesson planning competencies. Similarly, Allen, Webb and Matthews (2016) draw attention to the importance of being effective in STEM education for preservice teachers.

In previous studies made with the aim of researching into the STEM education in the preservice teacher education in Turkey, it was generally focused on the participants' attitudes and awareness levels related to the STEM education (Yalçın & Yalçın, 2018; Bakırcı & Karisan, 2018; Hacıoğlu, Yamak & Kavak, 2017; Kızılay, 2018; İnançlı & Timur, 2018). There are also STEM-based studies carried out during undergraduate education. In these studies, preservice teachers' various skills in the 21st century, their attitudes toward STEM implementations and their awareness levels about STEM were examined (Bozkurt, 2014; Çetin &Kahyaoğlu, 2018; Hacıoğlu, 2017). Besides these studies, Ercan (2016) examined preservice teachers' professional developments about the STEM education.

In this context, this study will contribute both to the development of preservice teachers' skills of preparing STEM-based lesson plans and to the related literature by analyzing difficulties encountered in the preparation of lesson plans.

1.1. Purpose of the Study

Developments in science and technology have not only affected societies in every area, but they have also caused new requirement to appear in the area of education. For this reason, like in many countries, the STEM education model has become widespread and was included in education programs in Turkey, too. The popularization of this education model had brought along the need for well-trained teachers.

For these reasons, the opinions of Physics-Chemistry teacher candidates regarding the application of STEM lesson plan were investigated.

2. Method

2.1. Research Model

In this study, it was decided to use the content analysis, one of the qualitative research methods. For this reason, case study analysis which is one of the descriptive analysis methods, was used to obtain the data and answers were sought for the research questions. According to Çepni (2018), content analysis required in-depth analysis of the collected data and allowed for the explication of previously unclear themes and dimensions.

2.2. The Study Group

The criterion sampling method, one of the purposeful sampling methods was used in the study. According to the criterion sampling method, the participants should be selected among the individuals with certain qualifications (Büyüköztürk, Akgün, Karadeniz, Demirel & Çakmak, 2009). In this study, the preservice teachers' having comprehensive knowledge in relation to STEM was determined as the criterion. In the purposeful sampling selection, the criteria considered to be important for the research subject are determined and the sample selected based on these criteria is considered to represent the research population in all respects (Yıldırım & Şimşek, 2013). All 60 pre-service physics-chemistry teacher, who studied pedagogical formation at a public university and took private teaching methods, constituted the study group.

2.3. Data Collection Tool

In the study, during the fall semester of the 2018-2019 academic year, the preservice teachers were asked to form real life-related, information-based problems covering the acquisitions included in the high school course programs and then they were expected to turn these into STEM lesson plans. The study was continued during six weeks with four lesson hours a week (Table 1).

Week	Hour	Procedures
1	3	Since the preservice teachers had general information about STEM, reminding them of the general STEM training and characteristics
	1	Answering the questions addressed by students about STEM
2	2	Presentation of a STEM lesson plan
	2	Discussing real life related, information-based problem examples Preservice teachers' writing real life related, information-based problems, which are in line with the high school curriculum
3	2	Presenting and discussing the information-based problems prepared by the preservice teachers in the classroom and elimination of examples not overlapping the scope
	2	Forming groups from the preservice teachers who want to work together on selected information-based problems
4	2	Turning real life related, information-based problems into course programs in line with the high school curriculum
	2	Searching and arranging necessary visual materials
5	2	The groups' presenting the prepared STEM lesson plans in the classroom
	2	Making evaluations and discussing the plans together with the class
6	4	Filling in the forms including open-ended questions related to the preparation of the Stem plans and one-to-one interviews

Table 1. Working plan

The data of the study was obtained via the forms prepared by the researchers and including open-ended questions and one-to-one interviews. The questions prepared for internal validity were presented to the opinion of two experts who studies in the field and finalized by making the necessary corrections. For the reliability of the study, the reliability formula suggested by Miles and Huberman (1994) was applied and the reliability of the study was calculated as 91%. The following measurement tool with open-ended questions was distributed to the students.

Scale Questions:

1. What difficulties do you have while preparing lesson plans? What are the reasons? Please, explain!
2. What do you think are the possible difficulties in doing lessons in accordance with the STEM lesson plans? Please, write these difficulties according to the order of importance.
3. What characteristics and skills do you think the teaching of lessons in accordance with the STEM plan develops in students? Please explain.

2.4. Data Analysis

Qualitative data obtained by analyzing the answers given to open-ended questions were analyzed in accordance with the content analysis method. The purpose of the content analysis is to gather data, which is similar to one another meaningfully, under codes and themes (Çepni, 2018). Firstly, thoughts and approaches expressed in relation to each question were examined one by one and turned into short codes. During the process of coding the data, the data was worked on and evaluated a few times and opinions were taken from expert academic members. By taking the similarities and the differences between the codes into consideration, the categories were formed and then it was passed from the categories to the themes. In the study, direct quotations from the opinions of teacher candidates are also included. Since the opinions of the teacher candidates were directly conveyed with their own sentences, each teacher candidate was given code names such as S1, S2, ……S60.

3. Findings

When the data belonging to the answers given by the preservice teachers was examined, the following findings were obtained for the first question and shown in Table 2.

Codes	f	%	Category	Theme
Determination of acquisitions Preparation of a Stem lesson plan for the first time Integration with scientific knowledge Reaching information Finding visual videos	9 4 16 5 6	15 7 27 8 10	Knowledge acquisition	Preparing a lesson STEM plan
Formation of information-based life problem Finding a solution to the problem Finding equipment/material Creative thinking Engineering integration Time	21 7 16 2 10 2	35 12 27 3 17 3	Idea development	Preparing a lesson STEM plan
Forming a prototype Material production	18 5	30 8	Product development	Preparing a lesson STEM plan
High cost of materials	5	8	Cost	Preparing a lesson STEM plan

Table 2. Results belonging to the analysis of the first question related to the difficulties encountered while preparing lesson plans and their reasons

As it can be seen from the table, sum of the frequencies does not give the number of participants since a teacher candidate may have specified more than one option regarding the difficulties in preparing the lesson plan.

Some sample explanations of the teacher candidates who participated in the study regarding the answer to the first question:

S24: The first reason for the difficulty which we had was that we prepared a STEM lesson plan for the first time, but we overcame the questions thanks to our teacher's directions.

S22: It was difficult to find the materials to use during the stage of designing materials.

S11: We had difficulty mainly in finding the information-based life problem when we prepared the lesson plans. For, we were required to design a material in relation to the solution to this problem.

S19: We had difficulty in finding an information-based life problem and designing materials with mathematics-engineering-science content.

S16: We had difficulty at the stage of the implementation of the prototype when preparing the lesson plan. We could not form a sponge city as we had suggested in the solution of our problem. This made us have difficulty in terms of time and cost.

Codes	f	%	Category	Theme
Shortage of time	8	13	Determination of conditions	Doing a lesson via the STEM plan
Lack of planning	5	8		
Classroom environment	3	5		
Difficulty in reaching information	10	17		
Differences between students' levels	5	8		
Teachers' incompetencies	5	8		
Integration with scientific knowledge	7	12		
Difficulty in the integration of pieces of information	10	17		
Integration with scientific knowledge	7	12	Integration	Doing a lesson via the STEM plan
Difficulty in the integration of pieces of information	10	17		
Use of technology	5	8		
Designing in line with the problem	6	10		
Contribution related to the acquisitions	5	8		
Use of the prototypes	8	3		

Table 3. Results belonging to the analysis of the second question including difficulties which are likely to be encountered while teaching lessons in accordance with the STEM lesson plans

When the answers given by the preservice teachers to the second question stated as "What are possible difficulties to be encountered in doing lessons in accordance with the STEM lesson plans?" were examined, it was observed that the preservice teachers stated opinions as it was shown in Table 3.

Some sample explanations of prospective teachers participating in the study regarding the answer to the second question:

S15: The prototype which we designed was a waste water treatment system prototype. However, we could not use it in the classroom environment and purify the dirty water.

S13: Since doing a lesson according to the STEM lesson plan requires a very comprehensive and detailed preparation, it takes a lot of time. If videos used to motivate students are not appropriate for the class level, students do not watch the lesson carefully.

S10: It is very important to integrate the knowledge of engineering, technology, science and mathematics. If this cannot be achieved, it creates a big difficulty.

S9: It is necessary that the information to be used in the problem which we used should be in line with the knowledge which the student has learned before. Moreover, since there will be a noisy environment in crowded classrooms, students may have difficulty in understanding the design or implementing the prototype.

S48: It is necessary that a teacher, who is supposed to do a lesson in accordance with the STEM lesson plan, should have a good interest in technology and also establish interdisciplinary relation ships well.

In the third question, the preservice teachers were expected to explain the characteristics and the skills to be developed by the implementation of a lesson in accordance with the STEM plan in students and the findings were given in Table 4.

Codes	f	%	Category	Theme
Visual memory and mental ability	9	15	Cognitive development	Development
Thinking like an engineer	4	7		
Analytical thinking	7	12		
Creativity	5	8		
Solution-oriented thinking	11	18		
Effective, permanent learning	5	8		
Problem solving	21	35		
Inquiring	3	5		
Researching skill	4	7		
Collaborative work C	7	12		
Concretizing abstract concepts	10	17		
Sense of responsibility	2	3		
Designing	5	8		
Manual skill	6	10	Psychomotor development	Development
Skill of developing materials	2	3		
Forming a prototype	8	13		

Table 4. Results belonging to the analysis of the third question related to the characteristics and the skills developed by doing a lesson in accordance with the STEM plan in students

When the study data was examined, the preservice teachers were observed to state that doing a lesson with the STEM lesson plan would develop mental ability more than psychomotor skills in students.

Some example explanations written by the preservice teachers in relation to the third question are as follows:

S26: It develops visual memory and mental ability.

S23: Students know how to research in case of problems which they encounter in daily life and can propose a solution to them.

S18: The most effective learning is learning by doing, experiencing. For this reason, a teaching done via the STEM plan develops students not only in cognitive area but also in psychomotor area.

S56: Students approach problems analytically by thinking multi-directionally.

4. Conclusion

In this study, the preservice teachers were asked to form real life related, information-based problems in line with the high school physics and chemistry curriculum and then they were expected to turn these into the STEM lesson plans. In the study, it was found that teacher candidates had difficulty in creating information-based life problems in subjects of their choosing, as can be seen from the data in Table 2. Real life related, information-based problems require teacher candidates to think mathematically in order to find an algorithm, which is different from what they learned in the classroom. This depends on analyzing the problem well, asking correct questions and thinking critically. At this stage, what is expected from preservice teachers is to understand the content of the problem, which the information-based problem contains, well, search and find the scientific information aiming to solve this problem and form the course content with which they can transfer this information to students in the most concrete way. While forming the course content, covering the ministry of national education high school curriculum and associating the information with videos are the important details of these lesson plans. Following these steps, they were expected to complete the STEM lesson plans by achieving the stages of forming the ideas aiming to solve the determined problem, product development and product testing.

The codes and categories obtained as a result of examining the answers of the teacher candidates for the analysis of the first question regarding the difficulties and causes while preparing the STEM lesson plans are given in Table 2. As it can be observed from the data in Table 2, teacher candidates stated having difficulties in determining acquisitions, reaching information, integrating it with scientific knowledge and finding visual videos in the category of knowledge acquisition. In the category of developing ideas, such difficulties as forming an information-based real-life problem, proposing a solution to the problem, finding the materials required for the solution, integration of information into engineering rose to prominence. Finding an information-based real-life problem was the mostly-emphasized difficulty (35%). Moreover, in the category of product development, developing materials for the solution to the problem and developing a prototype were expressed as difficulties with a sum of 38%. However, high cost of materials was less emphasized.

When the answers given by the teacher candidates in relation to the analysis of the second question were examined, it was observed from the data in Table 3 that such difficulties as time planning, reaching information, differences between students' levels, teacher incompetency, integration with scientific knowledge, integration of pieces of knowledge and classroom environment were expressed in the category of determination of conditions. In the integration category, difficulties were expressed in integration with scientific knowledge, integration of information, use of technology, design suitable for the problem, contribution related to the acquisitions and use of prototypes. In order to do a lesson according to the stem lesson plan, it is necessary to include scientific knowledge into the process. 17% of the preservice teachers stated having difficulty in reaching scientific knowledge and 12% of them stated having difficulty in integrating with scientific knowledge. These findings are consistent with the findings of Mentzer, Huffman and Thayer (2014) in their study with 20 high school students. Researchers state that high school students find it difficult to use scientific knowledge when designing for the problem. Similarly, in a study by Vaino, Vaino and Ottander (2018), it was concluded that students have difficulties in accessing, transferring and using information while designing, and it is stated that deficiencies in scientific knowledge cause unrealistic designs. For this reason, the science-technology relationship should be emphasized clearly in physics, chemistry lessons. For example, it should be taught which scientific knowledge, result or data caused which technology to come out and they should be explained with examples. This approach may lead to more successful and effective engineering design process by strengthening students' interests and curiosity feelings.

When the results of the teacher candidates belonging to the analysis of the third question were examined, as it can be seen from the data in Table 4 it was found to make a contribution to the students' cognitive and psychomotor developments. In cognitive development, the opinion that the students would mostly develop in terms of solution-oriented thinking, visual memory and mental ability, analytical thinking, problem solving, concretizing abstract concepts, working collaboratively, thinking like an engineer, creativity, inquiring was stated. Moreover, in psychomotor development, it was stated that they would develop in terms of manual skills, material development and forming a prototype. In some studies on this subject, similar results were obtained with the findings of this study. It was emphasized by various researchers in some previous studies made on this subject that as teacher candidates' knowledge about the structure of the STEM education and experiences in relation to STEM-based implementations increased, their students' scientific process skills developed and their interests, motivations and competencies related to the STEM education increased (Bozkurt, 2014; Altan & Ercan, 2016; Çınar, Pırasa & Sadoğlu, 2016; Hacıoğlu et al., 2017).

5. Suggestions

Since STEM is important in terms of both integrating different disciplines and making contributions to skill development, its integration into lessons is of great importance for individuals of the future. In today's societies, it is aimed to raise individuals having the 21st century skills, establishing the STEM relationship and showing interest. In the direction of these goals, it is aimed to increase the STEM content information of preservice teachers and teachers. For this reason, it is important that preservice teachers should prepare STEM lesson plans with the aim of acquiring STEM-based implementation experiences. Furthermore, it is suggested that regulations to allow for implementing this approach in high school programs in our country should be made.

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References

Allen, M., Webb, A.W., & Matthews, C.A. (2016). Adaptive teaching in stem: characteristics for effectiveness. *Theory into Practice,* 55(3), 217-224. https://doi.org/10.1080/00405841.2016.1173994

Altan, E.B., & Ercan, S. (2016). STEM Education program for science teachers: perceptions and competencies. *Journal of Turkish Science Education,* 13, 103- 117.

Bakırcı, H., & Karisan, D. (2018). Investigating the preservice primary school, mathematics and science teachers' stem awareness. *Journal of Education and Training Studies,* 6(1), 32-42. https://doi.org/10.11114/jets.v6i1.2807

Büyüköztürk, Ş., Akgün, Ö.E., Karadeniz, Ş., Demirel, F., & Çakmak, E.K. (2009). *Bilimsel Araştırma Yöntemleri.* Ankara.Pegem Akademi.

Bozkurt, E. (2014). *Muhendislik tasarim temelli fen egitiminin fen bilgisi ögretmen adaylarinin karar verme becerisi, bilimsel sürec becerileri ve sürece yönelik algılarına etkisi* (The effect of engineering design-based science instruction on science teacher candidates' decision making skills, science process skills and perceptions about the process). Unpublished doctoral dissertation. Available at Turkish Thesis Center (No. 366313).

Bybee, R.W. (2010). What is STEM education. *Science,* 329, 996. https://doi.org/10.1126/science.1194998

Capobianco, B.M. (2013). Learning and teaching science through engineering design: insights and implications for professional development. *Association for Science Teacher Education Conference.* Charleston, SC.

Carr, R.L., & Strobel, J. (2011). *Integrating engineering design challenges into secondary STEM education.* Available at: https://files.eric.ed.gov/fulltext/ED537366.pdf

Çepni, S. (2018). *Araştırma ve Proje Çalışmalarına Giriş* (8th ed.). Trabzon, Celepler Matbaacılık.

Çetin, A., & Kahyaoğlu, M. (2018). STEM temelli etkinliklerin fen bilgisi ogretmen adaylarinin fen, matematik, muhendislik ve teknoloji ile 21. yuzyil becerilerine yönelik tutumlarina etkisi (The effects of stem based activities on pre-service science teachers attitudes towards science, mathematics, engineering and technology, and 21. century skills). *EKEV Academy Journal,* 22(75), 15-28. https://doi.org/10.17753/Ekev952

Çınar, S., Pırasa, N., & Sadoğlu, G.P. (2016). Views of Science and mathematics preservice teachers regarding STEM. *Universal Journal of Educational Research,* 4(6),1479- 1487. https://doi.org/10.13189/ujer.2016.040628

Diefes-Dux, H.A., Zawojewski, J.S., & Hjalmarson, M.A. (2010). Using educational research in the design of evaluation tools for open-ended problems. *International Journal of Engineering Education. Special Edition* 26(4), 807-819.

English, L.D., & Mousoulides, N. (2011). Engineering-based modelling experiences in the elementary and middle classroom. In Khine, M.S., & Saleh, I.M. (Eds.), *Models and modeling: Cognitive tools for scientific enquiry* (173-194). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-0449-7_8

Ercan, S. (2016). Improving prospective science teachers' integrated STEM teaching competencies. *International Conference on Education in Mathematics, Science & Technology (ICEMST).* Bodrum, Turkey.

Fitzallen, N. (2015). STEM education: What does mathematics have to offer? In Marshman, M., Geiger, V., & Bennison, A. (Eds.), *Mathematics education in the margins* (Proceedings of the 38th annual conference of the Mathematics Education Research Group of Australasia) (237-244). Sunshine Coast: MERGA.

Hacioglu, Y. (2017). *Fen, teknoloji, muhendislik ve matematik (STEM) egitimi temelli etkinliklerin fen bilgisi ogretmen adaylarının elestirel ve yaratici dusunme becerilerine etkisi* (The effect of science, technology, engineering and mathematics (STEM) education based activities on prospective science teachers' critical and creative thinking skills). Unpublished doctoral dissertation. Available at Turkish Thesis Center (No. 461483).

Hacioglu, Y., Yamak, H., & Kavak, N. (2017). The opinions of prospective science teachers regarding STEM education: the engineering design-based science education. *Gazi University Journal of Faculty of Education,* 37(2), 649-684.

Han, S., Yalvac, B., Capraro, M.M., & Capraro, R.M. (2015). In-service teachers' implementation and understanding of STEM project-based learning. *Eurasia Journal of Mathematics, Science & Technology Education,* 11(1), 63-76. https://doi.org/10.12973/eurasia.2015.1306a

Hsu, M.C., Purzer, S., & Cardella, M.E. (2011). Elementary teachers views about teaching design, engineering and technology. *Journal of Pre-College Engineering Education Research,* 1(2), 31-39.

Inancli, E., & Timur, B. (2018). Fen bilimleri ogretmen ve ogretmen adaylarinin STEM egitimi hakkindaki gorusleri (Science teacher and teacher candidates' opinions about STEM education). *International Journal of Science and Education,* 1(1), 48-66. *International Journal of Science and Mathematics Education,* 15(1), 1-4.

Kızılay, E. (2018). STEM alanlarinin birbirleri ile iliskisi hakkinda fen bilgisi ogretmen adaylarinin görüsleri (Pre-service science teachers' opinions about the relationship of stem fields). *Journal of Research in Education and Scoiety,* 5(2), 174-186.

Lawrenz, F., Gravemeijer, K., & Stephan, M. (2017). *Introduction to this special issue.* https://doi.org/10.1007/s10763-017-9815-5

Lou, S.J., Shih, E.C., Diez, C.R., & Tseng, K.H. (2011). The impact of problem-based learning strategies on STEM knowledge integration and attitudes: an exploratory study among female Taiwanese senior high school students. *International Journal of Technology and Design Education,* 21(2), 195-215. https://doi.org/10.1007/s10798-010-9114-8

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons: International comparisons of science, technology, engineering and mathematics (STEM) education.* Final report. Available at: http://dro.deakin.edu.au/eserv/DU:30059041/tytler-stemcountry-2013.pdf

Mentzer, N., Huffman, T., & Thayer, H. (2014). High school student modeling in the engineering design process. *International Journal of Technology and Design Education,* 24. 293-316. https://doi.org/10.1007/s10798-013-9260-x

Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis.* London: Sage Publication

National Academy of Engineering [NAE] and National Research Council [NRC] (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects.* Washington, DC: The National Academies Press. https://doi.org/10.17226/12635

National Research Council [NRC] (2012). *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering.* Washington, DC: The National Academies Press.

Shaughnessy, M. (2013). Mathematics in a STEM context. *Mathematics Teaching in the Middle School,* 18(6), 321-323. https://doi.org/10.5951/mathteacmiddscho.18.6.fm

Smith, J., & Karr-Kidwell, P.J. (2000). The interdisciplinary curriculum: a literary review and a manual for administrators and teachers. Available at ERIC database (ED443172).

STEM Task Force Report (2014). *Innovate: a blueprint for science, technology, engineering, and mathematics in California public education.* Dublin, California: Californians Dedicated to Education Foundation. Available at: http://www.cde.ca.gov/nr/ne/yr14/yr14rel71.asp

Stoner, M.A., Stuby, K.T., & Szczepanski, S. (2013). The engineering process in construction and design. *Mathematics Teaching in the Middle School,* 18(6), 333-338. https://doi.org/10.5951/mathteacmiddscho.18.6.0332

Thomas, T.A. (2014). Elementary teachers' receptivity to ıntegrated science, technology, engineering, and mathematics (STEM) education in the elementary grades. Unpublished doctoral dissertation. University of Nevada. Available at: https://scholarworks.unr.edu/handle/11714/2852

Tsai, H.W. (2007). A study of STEM instructional model applied to science and technology in junior high school. Unpublished doctoral dissertation. National Pingtung University of Science and Technology.

Vaino, K., Vaino, T., & Ottander, C. (2018). *Designing an ice cream making device: A design-based science learning approach.*

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.

Wendell, K.B., Connolly, K.G., Wright, C.G., Jarvin, L., Rogers, C., Barnett, M. et al. (2010). Incorporating engineering design into elementary school science curricula. *American Society for Engineering Education Annual Conference & Exposition.* Louisville, KY. Available at: https://ceeo.tufts.edu/documents/conferences/2010kwkccwljcrmbim.pdf https://doi.org/10.18260/1-2--16175

Yalçin, S.A., & Yalçin, P. (2018). Fen bilgisi ogretmen adaylarinin FeTeMM egitimi konusundaki metaforik algilarinin incelenmesi (The investigation of the metaforic perceptions of pre service science teacher on stem education). *International Journal of Social Science,* 70, 39-59. https://doi.org/10.9761/JASSS7705

Yıldırım, A., & ve Şimşek, H. (2013). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri* (9th ed.). Ankara: Seçkin Yayıncılık.

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