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Pre-Service Teachers' STEM Perspectives and STEM Integrations

Feral OGAN-BEKIROGLU
Marmara University

Fatma CANER
Marmara University

Abstract: In order to have a STEM implemented class, teachers need to hold certain skills and knowledge so that they can integrate technology and engineering concepts into their classroom practices. Learning science through engineering is challenging. If pre-service teachers' thinking about STEM is understood, more collective and instructional representation related to pre-service science teachers' learning about STEM education can be obtained. Therefore, for effective integration it is helpful to understand how pre-service teachers conceptualize STEM education. The purposes of this research were to identify pre-service physics teachers' STEM perspectives and to examine role of their perspectives in their STEM integration. Multiple case study design was implemented for this research. The participants were pre-service physics teachers enrolling in a state university. Pre-Service Teacher STEM Education Survey was used to determine the participants' STEM perspectives. Their lesson plans were examined to understand how they made STEM integration. Interviews were conducted to comprehend the role of pre-service teachers' perspectives in their integration. The participants' STEM perspectives were categorized as nested, transdisciplinary, interconnected, sequential, overlapping, and siloed. Engineering design process and real-world problem could be seen obviously in the lesson plans of the participants having transdisciplinary perspective. However, the participants seeing STEM components as sequential could not reflect this process to their lesson plans and wrote open-ended physics questions instead. Some participants whose perspectives could be categorized as soiled could not write performance goals and concepts to be taught. Results can be valuable in constructing theoretical framework of STEM education in teacher education programs.

Keywords: STEM, Pre-service Teachers, Perspective, Integration

Introduction

Bybee (2013), whose definition was adopted for this study, leaves STEM ill-defined and suggests that the most accurate definition may come from one's personal context and needs and explains the perspectives of nine different STEM education through visual presentations. Bybee (2013) offers a range of models to describe STEM education from various educational perspectives, ranging from STEM as a replacement acronym for science or mathematics to STEM as representing true integration across all four fields. He presents eight approaches for integration with a focus on STEM education. In these approaches, STEM refers to (a) science (or mathematics); (b) both science and mathematics; (c) science and the incorporation of technology, engineering, or mathematics; (d) a quartet of separate disciplines of science, mathematics, engineering, and technology; (e) science and mathematics that are connected by a technology or engineering program; (f) coordination across disciplines; (g) combining two or three disciplines; (h) complementary overlapping across disciplines; (i) a transdisciplinary course or program. Bybee demonstrates that this integration can be done in different ways as STEM 1.0 (single discipline), STEM 2.0 (two disciplines), STEM 3.0 (three disciplines) and STEM 4.0 (four disciplines) in creating the STEM curriculum. He states that these integrations can be done in five different ways such as coordinating, complementary, associating, linking and integrating. Bybee's integration model was obtained for this study.

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How teachers conceptualize, interpret, and subsequently enact STEM content and engineering impacts the learning experiences they provide in their classrooms (Diefes-Dux 2014). Although pre-service STEM teacher education should include STEM content, pedagogy, and conceptualization, the literature suggests no leading conception of STEM education, and little is known about teachers' thinking about STEM (Radloff & Guzey, 2016). More research is needed to identify teachers' beliefs about and conceptions of STEM to provide professional development for teachers about STEM integration. Therefore, the purposes of this research were to identify pre-service physics teachers' STEM perspectives and to examine role of their perspectives in their STEM integration.

Methodology

Multiple case study design was carried out for this research (Yin, 2014). The participants were 14 pre-service physics teachers enrolling in a state university. Four of them were male.

The implementation lasted 14 weeks under the STEM Education course prepared for the pre-service physics teachers. In the first week of the course, philosophy of STEM education was discussed. The Framework for K-12 Science Education ((NAE & NRC, 2014) lists five major ideas that are essential to the design of STEM learning environments and curriculum resources: 1) identifying a limited number of core disciplinary ideas of science, 2) using crosscutting concepts, 3) engaging students in scientific and engineering practices, 4) building integrated understanding across time, and 5) coupling scientific ideas, crosscutting concepts and scientific and engineering practices to develop integrated understanding. These five ideas were considered in planning the activities. Design-based science learning (Fortus et al., 2004) framed the study. The participants experienced engineering design based challenges, STEM design challenges, and thinkering activities by doing the following activities: Making the highest tower with spaghettis, my soup does not get cold, my egg does not break, walking bug, cars that are made with balloons, and the fastest roller coaster. The participants identified the problem, defined what is given by the problem, produced possible solutions, developed a prototype to show their solutions, and received feedback from their classmates

Various sources were used to collect data. Teachers' STEM Perspective Survey (Radloff & Guzey, 2016) comprised of 12 questions was administered to understand the participants' STEM perspectives. The survey included four closed-ended questions, two multiple-choice style questions, five open-ended questions, and one question utilizing a Likert scale. Radloff and Guzey (2016) designed the survey to gather information from teachers about their conceptualization of STEM education, to learn what STEM looks like to teachers from their illustrations, and to obtain a rationale for their illustration. Hence, the participants were asked to make a diagram or schema about how they figured out STEM education by using the letters S, T, E, M.

In order to assess the participants' STEM integration, each of them prepared a STEM lesson plan at the end of the course. STEM lesson plan rubric out of 100 was used to analyze their lesson plans and to capture how they made STEM integration. The participants' STEM perspectives were categorized as nested, transdisciplinary, interconnected, sequential, overlapping, and siloed (Bybee, 2013). Nested visualizations signify a view of STEM in which there is one overarching discipline (Radloff & Guzey, 2016). Transdisciplinary visualizations suggest a focus on the real-world, application-based nature of STEM and a completely integrated view of STEM (Radloff & Guzey, 2016). In interconnected visualizations, concepts, processes, and resources are coordinated across boundaries to separate disciplines (Bybee, 2013). Sequential visualizations follow most closely with conceptualizations of STEM as a series of or successive STEM disciplines (Radloff & Guzey, 2016). Overlapping visualizations show two overarching subjects, connected by lesser subjects (Radloff & Guzey, 2016). Siloed visualizations portray the way STEM is historically taught in schools—in isolation of each other (Radloff & Guzey, 2016). Interviews were conducted to comprehend the role of pre-service teachers' perspectives in their integration.

Results

As shown in Table 1, while five out of 14 participants had the instructional perspective, three of them had the transdisciplinary perspective, two of them had siloed perspective and the rest of two had sequential perspective. Whereas one participant had nested perspective the other one had interconnected perspective. Instructional perspectives, which are drawn from the data of this study, demonstrate an understanding of STEM directly involving teaching or learning method and problem solving path. As a result, six different visual representations of the perspectives were obtained.

Table 1. Perspectives, disciplines, integration and lesson plan scores of the participants

PARTICIPANT	PERSPECTIVE	DISCIPLINES	INTEGRATION	LESSON PLAN
Alfred	Instructional	PTEM	STEM 4.0	90
Zack	Instructional	PEM	STEM 3.0	81
Barbara	Siloed	PE	STEM 2.0	48
Nancy	Transdisciplinary	PTEM	STEM 4.0	92
Gabby	Transdisciplinary	PTEM	STEM 4.0	77
Calvin	Sequential	P	STEM 1.0	30
Aoron	Siloed	PM	STEM 2.0	43
Fatima	Instructional	PE	STEM 2.0	47
Sandy	Sequential	P	STEM 1.0	30
Ferdinand	Transdisciplinary	PEM	STEM 3.0	60
Rebecca	Nested	PEM	STEM 3.0	79
Oliver	Instructional	PEM	STEM 3.0	67
Nadia	Instructional	PE	STEM 2.0	59
Debby	Interconnected	PEM	STEM 3.0	66

P = Pyhsics, E = Engineering, M = Maths, T = Technology

Five participants having instructional perspective could reach STEM 4.0, STEM 3.0 and STEM 2.0 integration. One of them having STEM 4.0 integration thought that STEM was a new teaching method. The other one having STEM 3.0 integration believed that STEM was a learning method. Another one having STEM 2.0 integration thought that STEM was problem solving path or method. He needed to apply technology and to determine target grade, standards and mathematical thinking in his integration. One of the remaining two participants having instructional perspective could reach STEM 3.0 and needed to support in technology usage and preparation of STEM activity sheet for the students. Other remaining participant having instructional perspective could reach STEM 2.0 and needed technology and mathematical thinking support.

Transdisciplinary perspective represents a combination of all disciplines. For instance, as seen in Figure 1, the participant having this perspective brought science, technology, engineering and math from separate sources and combined them in one single box. Three participants having transdisciplinary perspectives could make engineering design, test their design, collect data, use technology, and have computing thinking. Hence, they could reach STEM 3.0 and STEM 4.0 integration models. They did not separate STEM disciplines from each other.

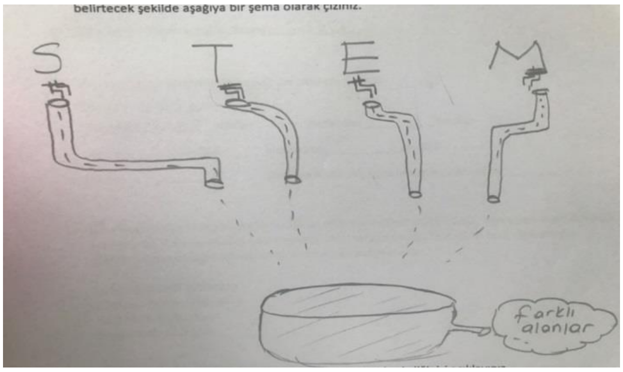

Figure 1. An example of transdisciplinary visual representation

Sequential perspective defines conceptualization of STEM as a series of the included disciplines. As can be seen in Figure 2, disciplines are represented in an order. Two pre-service teachers seeing STEM components as sequential needed to support in engineering design skills and computing thinking. They did not utilize technology. Therefore, they had STEM 1.0 integration model. They could not reflect this process to their lesson plans and wrote open-ended physics questions instead.

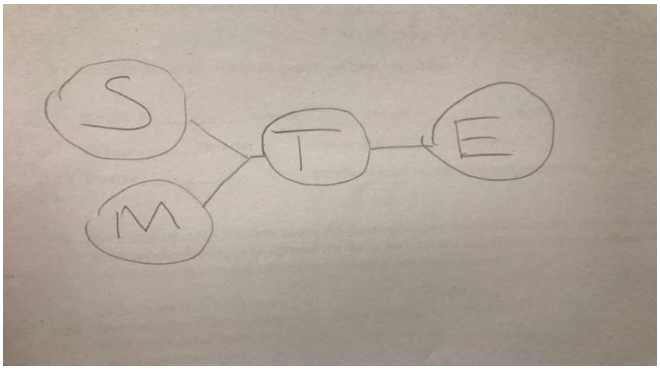

Figure 2. An example of sequential visual representation

On the other hand, one participant having siloed perspective whose visual representation is shown in Figure 3 used physics knowledge and engineering design while the other one used physics knowledge and computing thinking together. As a result, they could reach STEM 2.0 integration model. They did not benefit from technology. They could not write purposes of the lesson, performance goals, and concepts to be taught.

Since nested perspectives explain a visualization of STEM in which there is one inclusive discipline, the participant whose visual representation is displayed in Figure 4, combined all the disciplines under mathematics. This participant having nested perspective needed to support in technology using. She could reach STEM 3.0 integration.

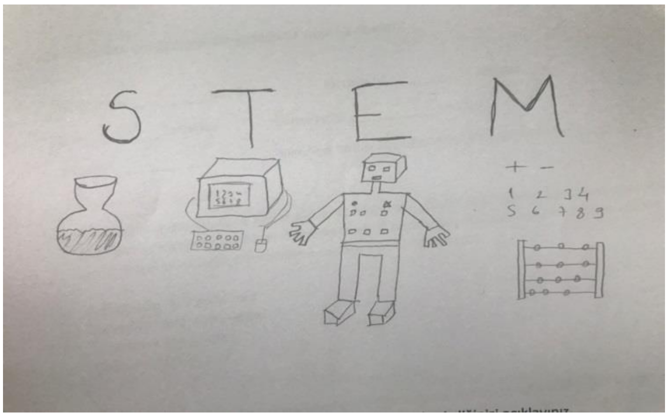

Figure 3. An example of siloed visual representation

Since nested perspectives explain a visualization of STEM in which there is one inclusive discipline, the participant whose visual representation is displayed in Figure 4, combined all the disciplines under mathematics. This participant having nested perspective needed to support in technology using. She could reach STEM 3.0 integration.

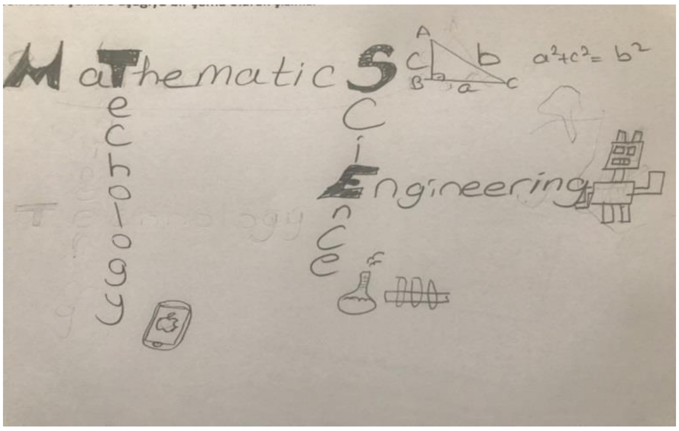

Figure 4. An example of nested visual representation

Implication and Suggestions

Results of this research can be valuable in constructing theoretical framework of STEM education in teacher education programs. Teachers' transdisciplinary perspective should be supported since it facilitates solving authentic problems. Teachers' knowledge of instructional technology should be improved. Inquiry based learning, problem based learning and project based learning should be implemented in teacher education to enhance teachers' STEM pedagogy.

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Author Information

Feral Ogan-Bekiroglu	Fatma Caner
Marmara University 6300 Ocean Drive #5825 Corpus Marmara Üniversitesi Atatürk Eğitim Fakültesi Fizik Eğitimi Anabilim Dalı Göztepe / İSTANBUL 34722 Contact e-mail: feralogan@yahoo.com	Marmara University Marmara Üniversitesi Atatürk Eğitim Fakültesi Fizik Eğitimi Anabilim Dalı Göztepe / İSTANBUL 34722