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The Effect of STEM Education on Pre-Service Science Teachers' Perceptions of 21st Century Skills and Competences and Problem Solving Skills[1]

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Abstract

In the globalizing world, individuals should be educated well-qualified to be effective citizens and workers by adapting the information society of the 21st century. At this point, STEM education is considered to promote the construction and improvement of 21st century skills and competences needed for individuals' living in today's world. In light of this consideration, the purpose of the current research is to examine the effect of STEM education on pre-service science teachers' (PSTs) perceptions of 21st century skills and competences and problem solving skills. In this research, a one group pre- and post-test design was conducted. The participants of the current study were 26 PSTs at a public university. The data of the study were collected with "21st Century Skills and Competences Scale" and "Problem Solving Inventory". In the data analysis, the paired sample t test was used. Findings revealed that there is a statistically significant difference among pre- and post-test total and sub-factors scores of PSTs' perceptions of both 21st century skills and competences and problem solving skills in favor of the post-test scores. These results suggest that STEM education have a potential to improve PSTs' perceptions of 21st century skills and competences and problem solving skills.

Keywords: STEM education, 21st century skills and competences, problem solving skills, perceptions, pre-service science teachers.

1. Introduction

In our century, globalization process has caused the social, cultural, economic and political changes and developments in many aspects. Individuals need to have some skills and competences for adapting to these changes and developments of the information and technology age. In this age, individuals should be well qualified in every aspect so that they can be effective citizens and workers by catching up the rapid developments all over the world. One of the most

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important ways to raise qualified individuals capabling of adapting to the necessities of own time is to improve educational processes, programs and policies. In the 21st century, being master at basic skills like reading, writing and mathematics is not enough and there is a need for qualified workers who can solve intellectual and technical problems (Wagner, 2008). In this manner, education programs should be organized for individuals to gain 21st century skills and competences like critical thinking, creativity, collaboration and problem solving skills. At this point, STEM education is considered to contribute to the improvement of 21st century skills and competences needed for daily and professional life. The number of research addressing the effect of STEM education on 21st century skills and competences and problem solving skills are not sufficient in the literature (Husin et al., 2016; Khanlari, 2013). Therefore, this research aims to explore the research questions:

- Is there any effect of STEM education on PSTs' perceptions of 21st century skills and competences?
- Is there any effect of STEM education on PSTs' perceptions of the problem solving process?

1.1 STEM education

In the recent times, STEM Education (the integration of Science, Technology, Engineering and Mathematics) has been used very often at science teaching in many countries all over the world. Gonzalez and Kuenzi (2012) stated that STEM education is an interdisciplinary approach that defines teaching and learning in the fields of science, technology, engineering and mathematics at all grade levels, including early childhood. STEM education aims to prepare the individuals for competent life and create a well-trained workforce for professions in the STEM fields (Bybee, 2013; Moore et al., 2014). STEM education supports to the improvement of 21st century skills needed to be found in qualified individuals today (Bybee, 2010; NRC, 2010). Today, international exams like PISA and TIMSS are now focusing on 21st century skills, which are critical thinking, collaboration, teamwork and problem solving (Greiff, Niepel & Wüstenberg, 2015; Kay, 2010) and this is evidence for the validity of 21st century skills (Greiff, Niepel & Wüstenberg, 2015). Beers (2011) stated that 21st century skills are compatible with the STEM's basic principles naturally. Therefore, today, there is a great emphasis on the STEM education which is one of the interdisciplinary approaches in education policies and programs.

1.2 *21st century skills and competences*

Today's developments in society and economy necessitate new educational systems serving to raise qualified individuals with 21st Century skills and competencies, who contribute actively to new forms of socialization and economic development. Ananiadou and Claro (2009) stated that 21st Century Skills and Competences can be defined as individuals are needed to be effective citizens and workers in the information society of the 21st century. These skills are addressed in three groups. Firstly, learning and innovation skills can be described as the skills for complex life and work environments in the 21st century. Secondly, in order to deal with the complexity of life and work environments, today's individuals need to promote adequate life and career skills. Thirdly, since people live in a technology and media-driven environment in this time, effective citizens and workers should be able to use information, media and technology skills (Partnership for 21st Century Learning, 2009).

1.3 *Problem solving skills*

Problem solving is resolution of a specific problem by using critical thinking skills (Kereluik, Mishra, Fahnoe & Terry, 2013). OECD defines problem solving as the capacity of an individual regarding being engage in cognitive processes to understand and solve problematic situations whose solution methods are not known (OECD, 2003). Therefore, problem solving skills is a complex process including cognitive, emotional and behavioral characteristics (Korkut, 2002). STEM education develops problem solving skills through an interdisciplinary approach (Buyruk & Korkmaz, 2016; Morrison, 2006; Stohlmann, Moore & Roehrig, 2012) and focuses on solving real-world problems in these approach-based learning environments. While making design in STEM, it is focused on solving the problem in particular because the engineering design process is one of the ways of problem solving such as scientific method, invention and innovation. Pre-service science teachers can enhance real-world problem solving skills of their students in future classrooms if they develop their problem solving skills.

2. Research methodology

2.1 *Research design*

The current research was designed with a one group pre- and post-test model as a quantitative research method. In this model, a single group is measured or observed both before and after exposure to the process (Cohen et al., 2007; Fraenkel et al., 2012). In current research, "21st Century Skills and Competences Scale" and "Problem Solving Inventory" were applied as pre-tests at the beginning of 'STEM Education' course. During 5 weeks, different activities regarding STEM education were applied to the pre-service science teachers. In order to investigate the effects of these activities on PSTs' perceptions of 21st century skills and competences and the problem solving skills, instruments were applied as post-tests after 6 weeks.

2.2 *Participants*

The participants of the present study were 26 pre-service science teachers in STEM Education course at a public university. PSTs have not any training about STEM Education before they participated in this research voluntarily.

2.3 *Procedures*

At the beginning of STEM Education course, "21st Century Skills and Competences Scale" and "Problem Solving Inventory" were responded by PSTs as pre-tests to reveal their perceptions of 21st century skills and competences, and problem solving skills. At the first week, information about the STEM education was made by the instructor. As from 2nd week, STEM practices started. Students designed different models as groups consisting of 5 or 6 students by integrating their knowledge in different fields (science, technology, engineering and mathematics) during 5 weeks (2 hours per week). Table 1 shows pre-service science teachers' STEM practices week by week. During the practices in STEM Education course, students thought and focused on how they can construct and design these models by discussing logical reasoning behind these models with their group mates. After 6 weeks, "21st Century Skills and Competences Scale" and "Problem Solving Inventory" were applied to pre-service science teachers as post-tests to determine their perceptions of 21st century skills and competences and problem solving skills.

Table 1. Procedure of STEM Education course

Weeks	Procedure
1st week	Presentation about the definition, history and importance of STEM education by instructor
2nd week	Fixed and movable pulleys, and gearwheels which turn in same and opposite direction
3rd week	Different swing bridge models
4th week	Space crafts, which have special properties like capabling of travelling, moving and carrying a load on Mars
5th week	Telescope models
6th week	Windmills and Carousels

2.4 *Data collection and analysis*

The data of this study were collected with two different instruments. The first instrument was the "21st Century Skills and Competences Scale". This scale was developed by Anagün et al. (2016) and includes 42 items consisting of 3 factors. The other data collection tool of the research was "Problem Solving Inventory". This inventory that describes people's perceptions about solving personal and daily life problems was developed by Heppner and Peterson (1982) and adapted to Turkish by Taylan (1990). The inventory is a 6-digit Likert-type scale, includes of 35 items and 3 factors. As suggested by the developers of the inventory, 3 items were removed and a total of 32 items were evaluated in data analysis. At this inventory, the highest score can be 192 and the lowest score can be 32. Low scores indicate that perception of problem solving skills is at high level, and high scores indicate that perception of problem solving skills is at low level. A paired-samples t-test, one of the parametric tests, was used in the analysis process of collected data since the difference scores of the two-related measures showed normal distribution.

3. Research results

In this study, the effect of STEM education on PSTs' perceptions of 21st century skills and competences and problem solving skills were examined.

The pre- and post-test results regarding total and sub-dimensions scores of the "21st Century Skills and Competences Scale" were given in Table 2. According to the pre- and post-test scores, there were statistically significant differences in favor of PSTs' post total test scores (t (25) = -5.057, p < .05) and post sub-factors test scores (t (25) = -4.150; 3.404; -3.894, p < .05).

Table 2. Perceptions of 21st century skills and competences

Factors		$\bar{X}$	N	df	t	p
Learning and Innovation Skills	Pre-test	59.28				
	Post-test	64.26	26	25	-4.150	.000
Life and Career Skills	Pre-test	73.50				
	Post-test	77.96	26	25	-3.404	.002
Information, Media and Technology Skills	Pre-test	32.11				
	Post-test	34.76	26	25	-3.894	.001
Total Scores of Perceptions of 21st Century Skills and Competences	Pre-test	164.91				
	Post-test	177.00	26	25	-5.057	.000

The pre- and post-test results regarding PSTs' perceptions of the problem solving skills were presented in Table 3. According to the findings, there were statistically significant differences in favor of PSTs' post total test scores (t (25) = 3.254, p<.05) and post sub-factors test scores (t (25) = 2.263; 2.625; 3.259, p<.05).

Table 3. Perceptions of the problem solving skills

Factors		$\bar{X}$	N	df	t	p
Problem Solving Confidence	Pre-test	32.15				
	Post-test	28.26	26	25	2.263	.033
Approach-Avoidance Style	Pre-test	34.88				
	Post-test	30.92	26	25	2.625	.015
Personal Control	Pre-test	18.69				
	Post-test	16.15	26	25	3.259	.003
Total Scores of Problem Solving Skill Perception	Pre-test	85.73				
	Post-test	75.34	26	25	3.254	.003

4. Discussion and conclusion

The effects of STEM education on pre-service science teachers' perceptions of 21st century skills and competences and the problem solving skills were examined in this research. Results of research revealed that PSTs' perceptions of 21st century skills and competences and the problem solving skills improved after STEM education. The present and previous research (e.g., Eguchi, 2014; Hacıoglu, 2021; Husin et al., 2016; Khalil & Osman, 2017) consistently supports the claim that STEM education has a potential to improve pre- and in-service teachers' 21st century skills. Khanlari (2013) investigated teachers' perceptions regarding the effects of the robotics, considered to be the practice area of STEM education, on teachers' 21st century skills. His research revealed that robotics is an effective tool for teachers to develop their 21st century skills including creativity, collaboration and teamwork, self-direction, communication skills, social and intercultural skills, and social responsibility. Therefore, it can be concluded that one of the important steps for the improvement of 21st century skills and competences is to include STEM education approach in teacher education programs and train pre-service and in-service teachers about STEM education. In addition, this research showed that PSTs' perceptions of the problem solving skills developed with STEM education. In related literature, there are several studies which

claim that STEM education improves students' problem solving skills (Buyruk & Korkmaz, 2016; Morrison, 2006; Stohlmann, Moore & Roehrig, 2012). The present century necessitates the adaptation of individuals to new situations. Therefore, today, 21st century skills and competences including also problem solving skills play an important role on both in daily and professional life. In this context, education should serve for the improvement of these skills and competences. One of the main aims of STEM education is to enhance individuals' 21st century skills and competences and problem solving skills. Teachers have a significant role on the improvement of learners' perception of 21st century skills and competences and problem solving skills. Therefore, if pre-service science teachers are educated well and their perceptions of 21st century skills and competences and problem solving skills are improved at the teacher training programs, they can help the improvement of their students' 21st century skills and competences and problem solving skills in the future.

5. Limitations and future research

Since STEM Education course has a limited capacity, one of the most important limitations for this research is the limited number of pre-service science teachers. In future studies, research can be conducted with more participants. In this study, the effect of STEM education on PSTs' perceptions of 21st century skills and competences and problem solving skills were investigated with a single group pre- and post-test model. By conducting this research with pre- and post-test control group design, the validity and reliability of research can be improved in the future studies. In addition, only quantitative research method was used in this research. In order to get in-depth results about PSTs' perceptions of 21st century skills and competences and problem solving skills, research can also be conducted with qualitative approach. On the other hand, this study can contribute to the literature in terms of providing important findings to the researchers, science teacher educators and experts who decide science teacher training programs and science curriculum about development of the perceptions of 21st century skills and competences and problem solving skills of PSTs who are future science teachers.

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