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Effectiveness of STEM-based Instruction: Preservice Mathematics Teachers' Opinions and Its Effects on Self Efficacy

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Research Article

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ABSTRACT

This study explored the effects of STEM-based instruction on the mathematics teaching self-efficacy of preservice mathematics teachers and their opinions about STEM-based instruction. A total of 23 senior preservice mathematics teachers participated in the current study. The concurrent mixed method design, which is characterized as collecting two types of data (qualitative and quantitative) at the same time, was utilized. Data were collected through Mathematics Teaching Efficacy Belief Instrument (MTEBI) and open-ended questionnaire developed by the authors. Results suggested that mathematics teaching self-efficacy scores of preservice mathematics teachers differed significantly in favour of post-instruction. The number of participants who felt competent to integrate STEM disciplines increased after the instruction. Moreover, STEM-based instruction improved preservice mathematics teachers' personal beliefs concerning mathematics teaching efficacy and mathematics teaching outcome expectancy. Another important finding was that the preservice mathematics teachers' awareness about the connection between mathematics and other disciplines was improved and they felt more capable of integrating STEM disciplines after STEM-based instruction.

Keywords: STEM, STEM-based instruction, self-efficacy, preservice mathematics teachers

STEM Temelli Öğretimin Etkililiği: Matematik Öğretmen Adaylarının Görüşleri ve Öz Yeterliklerine Etkisi

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ÖZ

Bu çalışma, STEM tabanlı öğretimin, matematik öğretmen adaylarının matematik öğretimi öz-yeterliği üzerindeki etkisini ve STEM tabanlı öğretime ilişkin görüşlerini incelemektedir. Çalışmaya 23 matematik öğretmeni adayı katılmıştır. Çalışmada aynı anda iki tür verinin (nitel ve nicel) toplanması olarak karakterize edilen eşzamanlı karma yöntem deseni kullanılmıştır. Veriler, Matematik Öğretimi Özyeterlilik İnancı Ölçeği ve açık uçlu sorularla toplanmıştır. Sonuçlar, matematik öğretmeni adaylarının matematik öğretimi öz-yeterlik puanlarının son test lehine önemli ölçüde farklılaştığını göstermektedir. STEM disiplinlerini bütünleştirme konusunda yetkin hisseden katılımcı sayısı uygulamadan sonra artmıştır. STEM tabanlı öğretim, matematik öğretmeni adaylarının matematik öğretim yeterliliği ve matematik öğretimi sonuç beklentisi ile ilgili kişisel inançlarını iyileştirmiştir. Diğer bir önemli bulgu da matematik öğretmen adaylarının matematik ve diğer disiplinleri ilişkilendirme hakkındaki farkındalıklarının arttığını ve STEM disiplinlerini entegre etme konusunda kendilerini daha yeterli hissettiklerini ortaya koymuştur.

Anahtar Kelimeler: STEM, STEM temelli öğretim, öz-yeterlik, matematik öğretmen adayları

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Introduction

Over a few decades, policy documents (e.g., 'European Commission of the Expert Group on Science Education' and 'Ministry of National Education in Türkiye') in all around world emphasize the need of STEM education (Hazelkorn et al., 2015; Ministry of National Education [in Turkish MEB], 2018a). For instance, in Science Education for Responsible Citizenship Report by European Commission highlights the importance of linking science with other disciplines including art, humanities, engineering and mathematics (Hazelkorn et al., 2015). In Türkiye, Turkish Industry and Business Association (in Turkish TUSIAD) made a similar call for increasing the number of students in STEM fields by focusing on STEM education (TUSIAD, 2014). This call also triggered the STEM education movement in Türkiye. In 2016, MEB prepared a STEM education report which proposing establishing STEM centres, conducting STEM education research and updating curriculum (MEB, 2016) and supporting teaching environments in schools. In line with these proposals, STEM education has accelerated in Türkiye. Curriculum revisions accompanied this report and current science curriculum in grades 3 to 8 has restructured in line with STEM approach (MEB, 2018a). For instance, this curriculum focused developing students' engineering and design skills by integrating science with mathematics, technology and engineering. This kind of integration also has been a central perspective in revised mathematics curriculum in Türkiye (MEB, 2018b). While mathematics curriculum has aimed to develop students' competencies in mathematics, science and technology; integrating mathematics with different disciplines including life sciences, social sciences, art and aesthetic is proposed for effective teaching (MEB, 2018a, 2018b). As mentioned so far, it is seen that the importance of STEM integration has been emphasized in many report and curriculum reforms. While these reports and programs strongly focuses on the developing 21st century skills, there seems one crucial question left unanswered: What STEM education offers for each discipline constructing STEM acronym? The literature shows that there is unbalanced representation for each discipline of STEM (i.e., English, 2016, 2017; Fitzallen, 2015). Nevertheless, English (2016) states that mathematics discipline benefits less from STEM integration. Still, Fitzallen (2015) argues that STEM integration can provide fruitful context for mathematics classrooms. On the other hand, available studies reported that teachers often struggled to implement STEM in their classes (Gardner & Tillotson, 2019; Parker et al., 2015; Ryu et al., 2019; Stohlmann et al., 2012). The struggle may be stemmed from teachers' preparedness to teach integrated STEM in their classes as Ryu et al. (2019) indicated. Apart from the content knowledge in the subjects being integrated, teachers' self-efficacy and confidence in STEM disciplines were considered as limiting factors that hinder effective STEM integration (Honey et al., 2014). Thus, various programs have been designed to support in-service teachers' confidence and self-efficacy to teach integrated STEM (e.g., Nadelson et al., 2012). Indeed, similar support is also needed for pre-service teachers (Corlu et al., 2014; Stohlmann et al., 2012). As an effort to prepare pre-service teachers' confidence in teaching integrated STEM, some studies sought ways to design courses for pre-service science teachers (Akaygun & Aslan Tutak, 2016; Ryu et al., 2019). However, these studies focused on enhancing pre-service science teachers' skills and confidence to teach integrated STEM. This study is differentiated from existing studies by means of designing a course for enhancing mathematics teaching self-efficacy of pre-service mathematics.

In following section, a review of current literature on integrated STEM education and teacher education as well as self-efficacy is discussed.

Integrated STEM Education

The relevant research on the subject presented reasonable evidence that integrated STEM teaching increased students' achievement (Brophy et al., 2008; Moore et al., 2015) and motivation (Howes et al., 2013; Moore et al., 2015; National Research Council [NRC], 2012; Stohlmann et al., 2012), while fostering their creativity, higher order thinking skills, problem solving skills and 21st century competencies (Howes et al., 2013; McDonald, 2016) as well as improving their self-efficacy (Sanders, 2009). However, Honey et al. (2014) suggested to interpret these positive outcomes cautiously since the integration of different STEM disciplines may have different effects on student outcomes. Honey et al. (2014) insisted that there is limited evidence of STEM integration for positive impact on mathematics outcomes. Supporting this, English (2016) argued that mathematics discipline benefits less from STEM integration. The difference in benefits of each discipline from integrated STEM education may be stemmed from different epistemological assumptions of each discipline (Williams, 2001). The differences and similarities as well as the relationship among STEM disciplines were not clearly understood as Williams (2001) indicated. Moreover, ambiguities in assessment procedure (what to assess and how) may be another reason (Pitt, 2009). In addition, traditional assessment techniques focus on knowledge gains of a single discipline while ignoring integrated STEM (Honey et al., 2014).

There is a substantial body of research reporting that there are barriers to the successful STEM integration such as the curriculum that do not support integrated STEM instruction (Blackley & Howell, 2015), centralized high-stake exams (Daugherty et al., 2014), and teachers being unprepared for teaching integrated STEM instruction (Blackley & Howell, 2015; Honey et al., 2014; McDonald, 2016; Ryu et al., 2019; Williams, 2001). In addition, there is a discrepancy about the alignment between how policy and schooling system perceive STEM (Blackley & Howell, 2015; Wong et al., 2016). Yet, country policies posture

STEM education agenda and accordingly, many countries has prompted STEM education (Ritz & Fan, 2015). Türkiye is one of these countries which has aimed to implement integrated STEM education and enforce integration among different STEM and non-STEM disciplines (such as art or social sciences). Still, it is a new approach which needs more empirical basis.

Self-Efficacy in integrated STEM Education

Self-efficacy can be considered one of the strongest predictors of individuals' behaviour (Pajares, 1992). Bandura defines self-efficacy as individuals' judgments of their personal capability (Bandura, 1997). Teachers with low teaching self-efficacy expend little effort in teaching, whereas teachers with high self-efficacy tend to use challenging activities and help students who are having difficulty in the learning process (Schunk, 2012).

Self-efficacy is also assumed to be a key factor in STEM performance and perseverance (Rittmayer & Beyer, 2008). STEM self-efficacy influences one's confidence and learning experiences, which result in working harder to accomplish tasks (MacPhee et al., 2013). Since the students' confidence in accomplishing tasks is closely related with teachers' classroom practices, teachers' self-efficacy in STEM has become more important. Content knowledge, pedagogical content knowledge along with teachers' self-efficacy beliefs about accomplishing STEM disciplines in their classrooms all shape students' interest and motivation in STEM (McDonald, 2016). Thus, teachers' self-efficacy within STEM integration is considered to be extremely important for successful teaching (Stohlmann et al., 2012).

Perseverance in STEM depends on perseverance in mathematics, and math perseverance can be predicted by affective characteristics such as self-efficacy (Czocher et al., 2020). Besides, there is a relationship between students' mathematics self-efficacy and their interest in STEM careers, and students with higher mathematics self-efficacy are more persistent in STEM than students with low mathematics self-efficacy (Kwon et al., 2019). In addition, there are studies showing that STEM education increases pre-service teachers' beliefs, confidence and self-efficacy towards STEM (Akaygun & Aslan Tutak, 2016; Nadelson et al., 2012; Ryu et al., 2019), but no studies have been found on the discipline specific efficacy of any discipline constructing STEM acronym. Thus, there is a need for intervention studies to support pre-service teachers' discipline-specific self-efficacy beliefs in STEM instruction (see Charleston & Leon, 2016; McDonald, 2016). In this respect, the current study examined the role of STEM experience in mathematics teaching self-efficacy of pre-service teachers.

Purpose and Importance of the Study

Self-efficacy belief of teachers in STEM education is a topic that has been investigated in many studies (Charleston & Leon, 2016; DeChenne et al., 2012; Prentiss-Bennett, 2016). However, no empirical study has been encountered that examine the effect of STEM-based instruction on the mathematics teaching self-efficacy of preservice mathematics teachers (PTs from now on). For instance, Prentiss-Bennett (2016) investigated elementary teachers' self-efficacy in teaching STEM. She reported that while elementary teachers had high self-efficacy with regard to STEM instruction, the teachers insisted that they needed support during STEM instruction. Besides there are many studies exploring mathematics teachers' (Stevens et al., 2013) and preservice teachers' self-efficacy (Çakıroglu & Isiksal, 2009; Işıksal, 2005). However, the studies focusing on mathematics teachers' self-efficacy is beyond the scope of our research. On the other hand, Ross, Beazley, and Collin Ross et al. (2001) stressed that teachers have insufficient self-efficacy in integrating STEM disciplines. Thus, there is a need for intervention studies to support teachers' discipline-specific self-efficacy beliefs in STEM instruction (Charleston & Leon, 2016; McDonald, 2016). Considering that mathematics discipline benefits less when compared to other disciplines in integrated STEM learning and teaching environment (English, 2016), it is important to examine the mathematics teaching self-efficacy of PTs in the process of acquiring STEM experience. Since, there is little evidence to suggest that STEM-based instruction effects on PTs' mathematics teaching self-efficacy.

Besides mathematics being an indispensable part of the integrated STEM approach, studies mainly focused on the other disciplines while ignoring the role of mathematics (English, 2016). In addition, English (2016) stressed that the outcomes of integrated STEM teaching and learning were under-researched. Therefore, in this study we focused on the effectiveness of STEM-based instruction on the mathematics teaching self-efficacy of preservice mathematics teachers. While Charleston and Leon (2016) suggested that educational interventions are needed in order to improve teachers' self- efficacy in teaching integrated STEM. Stohlmann et al. (2012) indicated that teachers' self-efficacy is an important area that requires further investigation. In the related literature, no study has been found that examines whether or not there is any change in the mathematics teaching self-efficacy beliefs of PTs after attending one-semester-long STEM instruction. Therefore, we aimed to examine the effects of STEM-based instruction on the mathematics teaching self-efficacy of preservice mathematics teachers. We also aimed to examine PTs' opinions about STEM-based instruction. For this purpose, the research questions are as follows:

RQ1. How effective was the integrated STEM-based instruction on PTs' mathematics teaching self-efficacy levels?

RQ2. What were PTs' opinions about STEM integration after a semester-long STEM-based instruction?

RQ3. What were PTs' opinions – especially in mathematics education– about their self-efficacy to teach integrated STEM units?

Method

This study utilized qualitative and quantitative approaches in a single study defined as a mixed method design (Hanson et al., 2005). This method is preferred as we have three research questions with qualitative and quantitative approaches as well as two types of data – numerical and textual. Among the mixed method design approaches, the concurrent mixed method design, which is characterized as collecting two types of data (qualitative and quantitative) at the same time, was adopted (Creswell et al., 2003). In this design, priority may be given to either qualitative or quantitative data (Hanson et al., 2005). In this study, equal priority was given to both forms of data.

The Context of the Study

In Türkiye, there is a centralized teacher education system. All teacher education programs including preservice mathematics teacher education programs offered in private and public universities are regulated by the Council of Higher Education Council of Türkiye (in Turkish YÖK). This Council also determines the compulsory and elective courses offered in the curriculum (YÖK, 2007). The elective courses are offered in the 2nd and 4th year, and the name as well as the content can be determined by the course instructor in each institution. Two elective courses were offered at spring 2017 semester and the pre-service mathematics teachers were enrolled in the courses based on their willingness. One of the elective courses was *Science, Technology and Society* course which was designed by the authors. Though participating in the study was not a prerequisite for enrolling the course, the aim of the course was explained by the course instructor. All the pre-service teachers enrolling the elective course have confirmed their willingness to participate this study. One of the authors was the instructor of the corresponding course while the other supervised preservice teachers (PTs) during the course each week. The syllabus of the course was adapted to a STEM-based module. The course lasted 14 weeks including final projects. In first week, the Mathematics Teaching Efficacy Belief Instrument (MTEBI) and an open-ended questionnaire were administered to the participants as pre-test. The rationale of STEM, articles in STEM, and various national and international examples were presented to participants during the following three weeks. Then, the participants worked in groups to develop a STEM-based lesson plan based on integrating the four disciplines as a final task to complete the course. First, they prepared the draft versions and the researchers provided feedback to their lesson plans. After revising their plans based on the feedback, they prepared the final presentation of their STEM-based models and explained to the whole class how their models integrate the four disciplines. Then, the class discussed the models and provided improvement if there was any. In the final week, the MTEBI and open-ended questionnaire were administered as post-test. The projects that each group developed during the semester is presented in Table 1:

For instance, in Hydraulic lift design, the group members developed a prototype of a modern bulldozer that aimed to integrate mathematics concepts such as measurement, calculation, and unit conversion with science concepts of fluid pressure. In another project idea, In Stirling engine design, the group members developed a prototype of a heat engine. Their prototype was able to convert heat energy to mechanical work. During this project, they used mathematics concepts such as measurement and calculation as well as science concepts including energy conversion, simple machines and gears.

The experts evaluated the quality of the projects with some criteria as presented below:

- Applicability of projects within the class.
- Integration among STEM disciplines.
- Content knowledge accuracy
- Relatedness with science and mathematics curriculum.
- The timing and difficulty level

A project was considered successful if it met all the criteria above. Otherwise, the authors gave feedback about the inconsistencies of the project. Then, the group members worked on the inconsistencies and revised their project. The final presentation of the project consisted of the factually correct and working prototype of the model. The group members also completed study diaries about their progress and submitted them to the course instructor during the process. Thus, the quality of the projects was ensured.

Participants

The participants of this study were 23 fourth-grade preservice mathematics teachers (PTs) (16 female and 7 male) enrolled in a mid-size public university in Türkiye. In their last semester in the university, they enrolled in a course named 'Science, Technology and Society', which

Table 1. PTs' Groups and the Projects Developed Through the Course

Group number	Project name
1	Binary machine
2	Stirling engine
3	Greenhouse working with water vapour
4	Resistant bridge design
5	Hydraulic lift design
6	Accident preventing highway
7	Comfortable passenger seat

was offered in the spring semester as an elective course. Thus, all PTs completed general culture courses (i.e., History of Atatürk's principles and reforms, information technologies, foreign language, and Turkish language), pedagogical courses (i.e., introduction to education, educational psychology, teaching methods etc.) and mathematics courses (i.e., calculus, algebra) as well as basic science courses (i.e., physics) prior to their last semester. They also completed School Experience I in a public school in the fall semester, and they enrolled in School Experience II (teaching practice course) at the time of data collection. All the PTs reported that they had observed mathematics courses during school experience while 11 of them also tutored mathematics courses to middle school students privately. Among them, three tutored science courses as well. As the course offered was an elective course, all the PTs voluntarily participated in the study.

Data collection tools

Quantitative data were collected using the Mathematics Teaching Efficacy Belief Instrument (MTEBI) to see if there was any difference in the PTs' personal mathematics teaching self-efficacy beliefs and mathematics teaching outcome expectancy beliefs. Qualitative data were collected using an open-ended questionnaire.

Mathematics Teaching Efficacy Belief Instrument (MTEBI)

The Mathematics Teaching Efficacy Belief Instrument (MTEBI), which was adapted into Turkish by Çakıroğlu (2008), was used for gathering quantitative data. Developed by Enochs et al. (2000), MTEBI is a modified version of the Science Teaching Efficacy Beliefs Instrument (STEBI), which was originally developed by Riggs and Enochs (1990). MTEBI includes two dimensions –personal mathematics teaching efficacy beliefs (PMTE) with 13 items, and mathematics teaching outcome expectancy (MTOE) with eight items. MTEBI was designed as a five-point Likert–type instrument ranging from 1 'strongly disagree' to 5 'strongly agree'. While one could get a possible score ranging from 13 to 65 on the PMTE; the scores that could be gathered from the MTOE range from 8 to 40. Getting high scores on the PMTE indicates having high self-efficacy as a mathematics teacher and high scores on the MTOE reflects high expectations of the outcomes in mathematics teaching. The reliability values of PMTE and MTOE dimensions were computed as 0.77 and 0.65 respectively (Çakıroğlu, 2008). The instrument was administrated as pre-test at the beginning of the semester and as post-test at the end of the semester. For this study, Cronbach alpha values were computed as 0.81 and 0.61 for the pre-test; and as 0.67 and 0.71 for the post-test respectively. The variation in Cronbach's alpha values may be due to experimental intervention or random error of measurement.

Open-ended questionnaire

To investigate the second and third research questions of the study, we developed a questionnaire consisting of open-ended items. The questions used in the open-ended questionnaire were prepared by previous studies (i.e., Author A). In addition, the researchers added additional questions to get in-depth information on participants' self-efficacy about teaching integrated topics. After the questionnaire was constructed, three experts from the science and mathematics education department examined the questions in terms of clarity and understandability. There were six questions in the final questionnaire. The first four questions were designed to investigate the participants' ideas about the connection between mathematics and other disciplines (1. What do you think about the connection of mathematics with other disciplines? 2. How can mathematics be connected with other disciplines? 3. Do you think you would need other disciplines (i.e., science, technology, engineering) while teaching mathematics? 4. What do you think about the effectiveness of teaching mathematics by integrating with other disciplines?). The last two questions were to understand whether or not the participants had high self-efficacy in integrating mathematics with other disciplines (1. What do you think about your competence in teaching integrated STEM units? 2. What do you think about the self-efficacy sources that make you feel competent to teach integrated STEM units?)

Data Analysis

Analysis of Quantitative data

Data collected through MTEBI were analysed using a paired-sample *t*-test. After collecting the data, the items with negative wording were reversed and the normality assumption was checked using the Shapiro-Wilk test. As a result of the analysis, the scores in MTOE ($W(23)=0.46$, $p>.05$), PMTE ($W(23)=0.23$, $p>.05$), and total self-efficacy ($W(23)=0.40$, $p>.05$) showed normal distribution. Since these findings confirm the assumptions of the t test, the change in the scores of the MTOE, PMTE and total self-efficacy scores were examined using a dependent sample t test. In order to examine STEM-based instruction's effects, the effect sizes were calculated and t value was converted into r value. For this conversion, the equation $(t^2/(t^2+df))^{(1/2)}$ proposed by Field (2009) was used. Accordingly, it was noted that STEM-based instruction had a high effect on Cohen's criterion ($r>.5$) (Pallant, 2011).

Analysis of Qualitative Data

Content analysis was used to develop accurate insight into the data. Content analysis is a qualitative technique that is used to analyse text. This technique requires systematic coding, categorizing, and quantifying from textual information to ascertain trends and patterns in the texts (Gbrich, 2007). For data analysis, inductive approach steps suggested by Elo and Kyngäs (2008) were used. First, the open-ended questionnaires, which were administered both as pre- and post-test, were converted to excel file format. Then, units of analysis were selected. Notes, headings and descriptions were determined through the text (open coding). The codes representing some commonalities were created and the categories representing the similar codes were determined.

'Counting' is an interpretation technique used for qualitative data. In this technique, themes are given numerical forms representing the 'the number of times' which help researchers to make interpretation (Miles & Huberman, 1994). Thus, we used counting technique to show the most frequent themes found in PTs' responses and used these frequencies to make interpretation. One of the most common evaluation techniques used in showing the consistency of results, the interrater reliability, was calculated (Miles & Huberman, 1994). Data was coded by both the course instructor and the other instructor who has expertise in mathematics education. Then, the codes were compared and discussed. The interrater reliability in this study was computed as 94% showing the coding was compatible and reliable. Data analysis was completed by the researcher and the frequencies were calculated for each category. In addition, PTs' projects used for data triangulation. Each participant was given two initial letters 'PT' (preservice teacher) and a number (from 1 to 23) in order to keep their identities confidential.

Results

In order to answer our research questions (RQ1. How effective was the integrated STEM-based instruction on PTs' mathematics teaching self-efficacy levels?, RQ2. What were PTs' opinions about STEM integration after a semester-long STEM-based instruction? RQ3. What were PTs' opinions – especially in mathematics education– about their self-efficacy to teach integrated STEM units?), we first reported the findings of the Mathematics Teaching Efficacy Belief Instrument (MTEBI). Second, we focused on the major themes reflected in the open-ended questionnaire.

Findings from MTEBI

The teacher candidates' post-STEM-based instruction MTOE scores (M = 30.87, SD = 3.24) significantly differed from their pre-STEM-based instruction MTOE scores (M = 28.57, SD= 3.06), $t(22)=3.504$, $p<.05$, $r=0.60$. Likewise the post-instruction PMTE scores (M = 53.09, SD =5.70) significantly differed from their pre-instruction PMTE scores (M = 49.87, SD = 6.15), $t(22)=4.098$, $p<.05$, $r=0.66$. Considering the total score, the teacher candidates' post-instruction total self-efficacy scores (M = 83.96, SD =7.36) significantly differed from their pre-instruction MTOE scores (M = 78.43, SD = 7.96), $t(22)=4.965$, $p<.05$, $r=0.73$. As to these findings, it can be said that the MTOE, PMTE, and total self-efficacy scores of preservice mathematics teachers differ significantly in favour of post-instruction scores (see Table 2).

Findings from the Open-ended Questionnaire

To explore PTs' opinions about STEM integration and their perceived competency to teach integrated STEM units, we analysed the PTs' written responses to the open-ended questionnaire. The themes included reflecting PTs' opinions on STEM integration, and (2) themes reflecting PTs' opinions on STEM integration after a semester-long STEM-based instruction were presented below.

We first asked the PTs how mathematics connects with other disciplines. We believe that participants' acknowledgment of the connections between STEM disciplines is important for successful integration. Before instruction, most of the PTs indicated that mathematics can be integrated only with science topics. They were not aware of the connection between mathematics and other disciplines. For instance, PT 2 indicated:

Mathematics can be integrated with science. Let's think about formula of V=x.t [v=speed, x=distance travelled (meters), t=time (second)]. We can use this formula in both mathematics and science.

Another participant (PT 13) explained mathematics' connection with science as 'We can integrate the topic of oblique shot in physics with trigonometry in mathematics.'

There was also one participant (PT 20) who believed mathematics is intertwined with daily life but was unable to give specific examples. His explanation is provided below:

It sounds like it [mathematics] can be integrated with examples from daily life.

At the end of STEM instruction (see Table 3), all the participants indicated that mathematics can be integrated with different disciplines including science, engineering, and technology. Participants' opinions about the integration of mathematics with other disciplines was grouped into two themes: Integration and daily life connection. Under integration theme, PTs' responses were grouped science related, technology and engineering and other disciplines. Here, participants' opinions about connection of mathematics with other disciplines either focused on purely science, or other disciplines such as technology and engineering. For instance, one teacher (PT-8) explained how mathematics can be integrated with different disciplines as:

With a careful plan and programming, it [mathematics] could be integrated with any discipline in a meaningful way. For instance, while solving an environmental problem that has social dimensions as well, we can design a setting that can refine contaminated water [her group developed a water filtration system during the semester]. In this design, while solving an environmental problem we can use physics, mathematics, and technology together.

The second part of the open-ended questionnaire is designed to explore PTs' opinions about their perceived competency to teach integrated STEM units. We asked the PTs whether or not they felt competent enough to teach integrated STEM units. Before STEM instruction, all the PTs indicated that they felt moderately competent to teach integrated STEM units. While they indicated that they felt competent in terms of integrating mathematics with science and technology, they indicated that integrating these disciplines (science, mathematics, and technology) with engineering is quite difficult. Sample excerpts are provided below:

Table 2. Mathematics Teaching Efficacy Belief Scores Comparisons of Preservice Mathematics Teachers

Dimensions	Measurement	N	M	SD	t	df	p	r
MTOE	Pre-test	23	28.57	3.057	3.504*	22	.002	.60
	Post-test	23	30.87	3.238				
PMTE	Pre-test	23	49.87	6.145	4.098*	22	.000	.66
	Post-test	23	53.09	5.696				
Total	Pre-test	23	78.43	7.959	4.965*	22	.000	.73
	Post-test	23	83.96	7.358				

Note. MTOE = mathematics teaching outcome expectancy, PMTE = personal mathematics teaching efficacy beliefs, M = mean, SD = standard deviation, *r* = effect size. Levels of significance: $^{*}p < .05$

Table 3. PTs' Opinions About the İntegration of Mathematics With Other Disciplines After the Instruction

Themes	Explanation	Frequencies (f)	Sample excerpt
Integration	Science related areas (chemistry, physics, biology)	12	'…We need mathematics for measuring in science.'(PT22) '…Computational skills in mathematics are needed for physics formulas.' (PT7)
	Engineering and technology	4	'Mathematics can be integrated with engineering. We do need mathematics software for the motion of machines in engineering.' (PT6)
	Other disciplines	3	'It appears that many topics are not independent of each other. All the topics can be integrated.' (PT18)
Daily life connection	Intertwined with daily life	4	'…it [mathematics] is intertwined with daily life. For instance, while we are shopping, slicing a pizza or cake, or producing technological devices.' (PT21)

Table 4. Preservice Teachers' Perceived Barriers Which Made Them To Feel Partially Competent to Integrate STEM Disciplines Before Instruction

Barriers	Frequencies (f)*
Lack of content knowledge	8
Lack of integration among disciplines	5
Personal interest/curiosity	2

*PTs indicated more than one reason

"While science exists in daily life as well as in nature, we can easily integrate mathematics with daily life. Likewise, technology is a tool that helps facilitate mathematics. At that point, I am not sure how we can integrate these three concepts [mathematics, science and technology] with engineering." (PT 1)

"Science and mathematics are quite close disciplines. So, I believe I could integrate these two close disciplines. As mathematics lies at the core of technology, I could easily integrate mathematics with technology. However, I have no idea whether I could integrate mathematics with engineering or how I could integrate all of them." (PT 6)

"Mathematics contributes to science and vice versa. I am interested in technology and I would love to use technology in mathematics classes but I am not sure how to do it. I do not feel competent in terms of integrating mathematics with technology and engineering. I do not have the technical knowledge used in engineering either." (PT 23)

Other PTs feel partly competent in terms of integrating mathematics with technology and engineering. Sample excerpts exemplifying this opinion are provided below:

"As science exists in nature and in daily life itself, I can easily integrate mathematics with science. Furthermore, technology is a tool that can help me to teach mathematics effectively. However, I do not believe that I can use technology effectively at the moment. Derivative, integral calculus and differential calculations are used in engineering." (PT 2)

"I feel competent enough to integrate mathematics with science as I was very interested in science during high school. I feel moderately competent to integrate these disciplines [science and mathematics] as I watch the technology programs on TV. On the other hand, I do not feel competent enough to integrate these disciplines with engineering as because I do not have an engineer's perspective." (PT 13)

Before moving forward exploring the change in their opinions after instruction, we also examined why preservice mathematics teachers felt partially competent in terms of integrating mathematics with other disciplines. Their perceived barriers which made them feel partially competent are summarized in Table 4.

When Table 4 examined, we can see that many preservice mathematics teachers (n= 8) indicated that lack of content knowledge as a main barrier for successful STEM integration. Also lack of sufficient integration among disciplines (n= 5) and lack of personal interest for integrating STEM disciplines (n=2) were reported as barriers. Sample excerpts are provided below:

I do not have any knowledge about engineering but if I can learn more about the nature of engineering, I can integrate engineering with other STEM disciplines. (PT 6, lack of content knowledge theme)

I can integrate mathematics objectives with other disciplines separately (i.e., mathematics with science, or mathematics with engineering). However, I could not think of integrating all disciplines as a whole (PT 14, lack of integration among disciplines theme)

I am having difficulty in using technology during integrating disciplines. This is solely caused because of lack of personal interest in use of technology. I need reinforcement to develop my skills. (PT 1, personal interest theme)

At the end of the semester, the preservice teachers' opinions about the same questions changed with terms of competency they felt after the course. Their competency feelings about teaching integrated STEM unit can be grouped under two major themes as sufficient and partially sufficient. While the number of participants who felt competent to integrate STEM disciplines increased at the end of semester, there were some PTs who still felt difficulty in integrating STEM disciplines, particularly in integrating mathematics, science, and technology with engineering. Sample excerpts and related frequencies are presented below:

When the excerpts from PTs were explored, it can be seen that PTs mainly struggled with integrating other STEM disciplines with engineering. This finding, in fact, is no surprising as the teachers/preservice teachers were frequently reported as having difficulty in integrating science, mathematics and technology with engineering.

We also explored the sources of their competency to teach integrated STEM units. We asked PTs where they think their self-efficacy stems from. We believe that the sources they identified are important for understanding whether or not STEM instruction helped them to feel competent to teach integrated STEM units. We classified the responses of those PTs' competency sources into five themes: Private tutoring, personal interest/curiosity, positive attitude, gaining experience, and content knowledge (see Table 6).

When we compared PTs' responses after instruction, we realized that the number of PTs who identified their personal interest and curiosity as the main source of their competency to integrate STEM disciplines had increased. Moreover, gaining experience in integrating STEM disciplines and increasing content knowledge were other sources that they reported after the instruction. For instance, two PTs indicated that the teaching practice course also helped them gain self-efficacy to integrate STEM disciplines. While the *Science, Technology, and Society* course was an elective course, the teaching practice course was a required course that was offered at the 8th semester (last semester before graduation). Thus, they had a chance to implement their project ideas in real classroom settings. One preservice teacher (PT 3) indicated:

"I had a chance to implement what I learned during this course in a real classroom setting during the teaching practice course. Thus, I believe I can integrate STEM disciplines in a real classroom setting."

Also, one preservice teacher (PT 6) indicated: '*I feel competent to integrate STEM disciplines. While I have the required content knowledge in mathematics, I learnt how to integrate these disciplines based on the experience we gained during our project in this semester.*' We classified this response under the 'gaining experience' heading theme. Another preservice teacher (PT 8) stated:

Table 5. PTs' Opinions About Their Competency to Integrate STEM Disciplines After the Instruction

Theme	(f)	Sample excerpt
Sufficient	12	'I can integrate STEM disciplines. As science is everywhere in daily life and technology has become the centre of our daily life, integration of these disciplines has become a necessity. What is more, during the design process in engineering we use mathematics, science, and technology. Thus, I believe I can integrate these disciplines.' (PT 2) 'I can integrate mathematics with science based on the science and mathematics objectives in the curriculum. Besides, technology is a tool that I can use for doing research. I can integrate all these [mathematics, science, and technology] with engineering as most engineering topics are rooted in mathematics and geometry.' (PT23)
Partially sufficient	11	'I can integrate mathematics with science. What is important is realizing the connection of science objectives with mathematics. This is what we did this semester. I feel competent to integrate technology with mathematics and science. However, I do not feel competent enough to integrate engineering with the rest. I can only integrate mathematics with engineering by measurement and computation skills. I am still not sure how to extend this integration.' (PT14) 'I can integrate mathematics with science and technology. This semester, my friends and I developed a project for integrating different STEM disciplines. But I still do not feel competent enough to integrate mathematics, science and technology with engineering alone. I might need to get help from my friends for successful integration of whole STEM disciplines.' (PT11)

Table 6. Preservice Teachers' Reported Competency Sources After Instruction

Sources	Frequencies (f)*
Private tutoring	8
Personal interest/curiosity	8
Positive attitude	6
Gaining experience	5
Content knowledge	2

*PTs indicated more than one source.

"We continually prepared STEM-based materials throughout the semester. Moreover, computer-aided instruction helped me to feel more competent to integrate STEM disciplines. Thus, I believe I am competent to integrate STEM disciplines.

Discussion, Conclusion and Implications

In the present study, we explored the effectiveness of integrated STEM-based instruction on preservice mathematics teachers' mathematics teaching self-efficacy and also the opinions of preservice mathematics teachers about integrated STEM instruction.

The effectiveness of STEM teaching on PTs' mathematics teaching self-efficacy

The first research question was designed to investigate the effectiveness of integrated STEM -based instruction on PTs' mathematics teaching self-efficacy levels. The results suggested that integrated STEM-based instruction improved preservice mathematics teachers' personal mathematics teaching self-efficacy beliefs (PMTE), implying they had higher self-efficacy as mathematics teachers after the instruction. Similarly, PTs' outcome expectancy beliefs (MTOE) improved after STEM-based instruction implying their beliefs that their skilful instruction can balance the teaching environment. These results can be interpreted in three different ways: First of all, in the current study, PTs might have seen the relationship between mathematics and science with STEM-based instruction, so their self-efficacy might be significantly increased. According to Sanders (2009), teaching science and mathematics together can improve self-efficacy beliefs. Thus, their self-efficacy beliefs might also be improved. Another possible interpretation is the mastery experiences that PTs gained during the STEM-based instruction. According to Bandura (1986), one of the self-efficacy sources is enactive mastery experiences that serve as indicators of capability. Along with mastery experience, PTs also gained vicarious experiences by observing their peers' presentation of STEM projects as well as observing the instructors' feedback during the presentations. Moreover, their STEM projects and presentations also may contribute as an energizing factor that can contribute to a successful performance. All these factors (mastery experiences, vicarious experiences, and psychological reactions) are reported to be important sources of self-efficacy according to Bandura (1997). Thus, we believe PTs' mastery experiences, vicarious learning experiences, and their sense of successful performance might increase PTs' self-efficacy beliefs. However, it is difficult to interpret the increase in preservice teachers' self-efficacy as being due only to STEM-based instruction. Another possible interpretation of this increase can be the mentoring provided to teacher candidates during this elective course. In literature, mentoring is reported to influence academic achievement by providing emotional support and guidance as well as improving the confidence levels of participants (Liang et al., 2002). Moreover, teachers' specific role in creating their students' positive learning outcomes in integrated STEM-based instruction has also been highlighted by Honey et al. (2014). Thus, we believe mentoring provided by both the course instructor and the expert in mathematics education helped them design better integrated STEM projects, which resulted in them developing higher self-efficacy beliefs. This is also evident in the qualitative findings of this study. Overall, the course designed for integrated STEM teaching plus the mentoring as well as the mastery experiences gained by preparing an integrated STEM project all helped participants develop the desired self-efficacy in STEM. Although it is known that teachers' self-efficacy is not solely due to instruction or preparing an integrated STEM project, we can conclude that the increase in perceived self-efficacy of preservice teachers indicates that their belief in organizing or executing an integrated STEM course has increased (see Bandura, 1997). In this respect, it is possible to say that the PTs who enrolled in a STEM-based course have an increased chance at being successful in designing and carrying out STEM-based courses. Since self-efficacy can be considered one of the strongest predictors of individuals' behaviour (Pajares, 1992), we expect to see their increased self-efficacy beliefs reflected in their classes.

PTs' opinions about the about STEM integration

The second research question was designed to investigate PTs' opinions about STEM integration after a semester-long STEM-based instruction. Thus, we explored the change in PTs' self-efficacy beliefs after the instruction utilizing qualitative data. We asked the PTs whether or not they felt competent to teach integrated STEM units. While all the PTs initially indicated that they felt partly competent to teach integrated STEM units before STEM instruction, their opinions changed at the end of the semester. More PTs post-instruction believed that they felt competent to integrate STEM disciplines when compared to their answers before STEM-based instruction. This finding supported our previous interpretation as PTs' mastery experiences, vicarious experiences, and psychological reactions as well as mentoring provided by the course instructor and the expert in mathematics education might all have helped them improve their self-efficacy beliefs. This was also evident in the self-efficacy sources that PTs reported. The self-efficacy sources that PTs reported also changed at the end of the semester. While the number of PTs who identified personal interest and curiosity as the main source of their self-efficacy to integrate STEM disciplines increased, two PTs indicated that the teaching practice course also helped them to gain self-efficacy to integrate STEM disciplines. This was supplementary evidence for our mastery experience interpretation. However, some PTs still felt difficulty in integrating STEM disciplines, especially integrating mathematics, science, and technology with engineering. This result is in parallel with the previous studies, which reported engineering as a challenge for integrating other STEM disciplines (English, 2016). This might have resulted in inadequate self-efficacy beliefs in integrating STEM subjects (Ross et al., 2001). To overcome the difficulty of integrating engineering with other STEM disciplines, more curricular support and training are reported. This also will result in improving PTs' competencies to teach integrated STEM concepts (Prentiss-Bennett, 2016). In this respect, gaining more experience, which is reported as a self-efficacy source by PTs, can help them feel more competent to integrate STEM disciplines. Similarly, some of the PTs stated that apart from the scope of the current study, the teaching practice course was a source for their self-efficacy. The PTs in the current study reported that interest and curiosity are among their sources of self-efficacy. When improving self-efficacy to integrate STEM disciplines, it is also important that teacher candidates have high personal interest and curiosity. As is known, interest and curiosity, which can influence one's psychological state, can also serve as a source of self-efficacy (Bandura, 1997).

PTs' opinions about their self-efficacy to teach integrated STEM units

The third research question was designed to investigate PTs' opinions – especially in mathematics education– about their self-efficacy to teach integrated STEM units. Thus, we explored PTs' opinions about how mathematics connects with other disciplines. The results showed that the participants were not fully aware of the connection between mathematics and other disciplines before the STEM-based instruction. They usually stated that mathematics can only be integrated with science. Their opinions, however, changed after the instruction. All the participants indicated that mathematics can be integrated with other disciplines. This is because all STEM disciplines are tended to be taught as isolated courses (see Blackley & Howell, 2015). Supporting this, English (2016) also argues for a balanced focus on STEM disciplines. Otherwise, mathematics and science, which have traditionally been placed in national curricula, tend to be focused on but independently of one another. Supporting this, the PTs in our study stated similar things about the connection between mathematics and science. They had never experienced connecting mathematics with engineering or technology before this elective course. They believed that science is taught in science classes only and the same for mathematics. This result explains why the students cannot easily establish connections among these disciplines. Making the connections among disciplines apparent, as was done in this elective course, helped PTs recognize the connection between mathematics and other disciplines, as evidenced in our post-instruction responses. Mathematics, on the other hand, is often downplayed in STEM studies (see English, 2016; Marginson et al., 2013). We tried to overcome this by conducting this study with preservice mathematics teachers. They were ready to teach mathematics as a profession but their ability to teach mathematics integrated with other STEM disciplines was limited before this course. At the end of STEM-based instruction, their self-efficacy beliefs to integrate STEM disciplines, and their opinions on integrating mathematics with other disciplines gradually improved. To sum up, STEM-based instruction may yield fruitful results in raising teachers who are aware of the integration of different disciplines. Actually, raising such aware teachers is crucial for raising students with 21st-century skills.

Implications

No study that examines the change in the mathematics teaching self-efficacy beliefs of PTs in a STEM-based instruction environment has been found in the related literature. Therefore, we believe that this research will provide valuable contributions to the field of STEM education. Thus, the empirical findings obtained from this study can contribute to the development of theoretical knowledge on STEM education and can also be used in the process of integrating STEM-based instruction into the curricula being used. In particular, the findings from the study can contribute to the design of integrated STEM-based instruction during the preparation of future teachers.

In addition, the findings obtained from the study may provide directions about the difficulties encountered in STEM-based instruction to mathematics educators. Consequently, the results of the study can provide mathematics educators and teachers with a perspective on STEM education. In this respect, instructors and curriculum makers might consider educational issues and activities according to the results obtained from the present study. More specifically, the results we presented here comprise the data collected from mathematics teacher candidates and their thoughts about the applicability of STEM education and can provide important information to researchers as mathematics is reported to be undervalued and under-researched in numerous studies as discussed above. Another direction for future research might be to compare the findings of this study with previous studies. (e.g., The opinions of science teachers about similar teaching experiences can be compared with the findings in this study). Such comparisons can provide important knowledge about how teacher candidates in different subject areas perceive similar STEM-based instruction. Besides, in STEM-based instruction, the preservice science teachers' science teaching self-efficacy beliefs may be examined. Thus, the effects of STEM instructions on discipline-specific teaching self-efficacy can be better understood. Also conducting a comparative study comprising science and mathematics teacher candidates in the same study could provide insight as to how different subject backgrounds interpret the same STEM-based instruction.

A feature that makes this study worthwhile is that experts in the fields of science and mathematics taught the elective course designed for STEM-based instruction together for 14 weeks. No similarly-run STEM study was encountered in the literature. Thus, collaboration between teacher educators in STEM-based instruction might provide another future research direction to be investigated.

Disclosure statement

We have no conflict of interest to declare.

Genişletilmiş Özet

Giriş

STEM eğitiminde öğretmenlerin öz-yeterlik inançları birçok çalışmada araştırılan bir konu olmasına rağmen (Charleston ve Leon, 2016; DeChenne vd., 2012; Prentiss-Bennett, 2016), literatürde STEM eğitiminin, matematik öğretmeni adaylarının matematik öğretimi öz-yeterliği üzerindeki etkisini inceleyen herhangi bir ampirik çalışmaya rastlanılmamıştır. Prentiss-Bennett (2016), ilkokul öğretmenlerinin STEM öğretimindeki öz-yeterliğini araştırdığı çalışmasında ilköğretim öğretmenlerinin STEM öğretimi konusunda yüksek öz-yeterliğe sahip olmalarına rağmen, öğretmenlerin STEM öğretimi sırasında desteğe ihtiyaç duyduklarını belirlemiştir. Öte yandan, Ross, Beazley ve Collin Ross vd. (2001), öğretmenlerin STEM disiplinlerini bütünleştirmede düşük özyeterliliğe sahip olduğunu vurgulamışlardır. Bu nedenle öğretmenlerin STEM öğretiminde disipline özgü öz-yeterlik inançlarına yönelik müdahale çalışmalarına ihtiyaç vardır (Charleston ve Leon, 2016; McDonald, 2016). Bütünleşik STEM öğrenme ve öğretme ortamlarında, STEM entegrasyonundan matematik disiplininin diğer disiplinlere göre daha az fayda sağladığı düşünüldüğünde (English, 2016), öğretmen adaylarının matematik disiplini bağlamındaki kazanımlarını belirlemek önemlidir: Bu kazanımlardan biri de matematik öğretimi özyeterliğidir. Çünkü, STEM tabanlı öğretimin öğretmen adaylarının matematik öğretimi öz yeterliliği üzerinde etkili olduğunu gösteren çok az kanıt vardır.

Matematik dersi bütünleşik STEM yaklaşımının vazgeçilmez bir parçası olmasına rağmen, matematiğin rolü göz ardı edilerek ağırlıklı olarak diğer disiplinlere odaklanan çalışmalar yapılmaktadır (English, 2016). Ek olarak, English (2016), bütünleşik STEM öğretimi ve öğreniminin sonuçlarının yeterince araştırılmadığını vurgulamıştır. Charleston ve Leon (2016), bütünleşik STEM öğretiminde öğretmenlerin öz yeterliliğini geliştirmek için eğitimsel müdahalelere ihtiyaç olduğunu öne sürerken, Stohlmann vd., (2012), öğretmenlerin öz yeterliğinin daha fazla araştırma gerektiren önemli bir alan olduğunu belirtmiştir. Bu nedenle, bu çalışmada STEM temelli öğretimin matematik öğretmeni adaylarının matematik öğretimi öz-yeterliği üzerindeki etkilerinin ve öğretmen adaylarının STEM tabanlı öğretim hakkındaki görüşlerinin incelenmesi amaçlanmıştır. Bu amaçlar doğrultusunda araştırma soruları şu şekilde belirlenmiştir:

S1. Bütünleşik STEM öğretimi, öğretmen adaylarının matematik öğretimi öz-yeterlik düzeyleri üzerinde ne kadar etkilidir?

S2. Bir dönem süren STEM tabanlı eğitimden sonra öğretmen adaylarının STEM entegrasyonu hakkındaki görüşleri nelerdir?

S3. Öğretmen adaylarının -özellikle matematik eğitiminde- bütünleşik STEM disiplinlerini öğretme öz-yeterlikleri hakkındaki görüşleri nelerdir?

Yöntem

Bu çalışmada, karma yöntem tasarım yaklaşımları arasında, aynı anda iki tür verinin (nitel ve nicel) toplanması olarak karakterize edilen eşzamanlı karma yöntem tasarımı kullanılmıştır (Creswell vd., 2003). Nitel ve nicel yaklaşımlarla cevaplanması gereken üç araştırma sorusu ve sayısal ve metinsel olmak üzere iki tür veri olduğu için bu yöntem tercih edilmiştir. Bu tasarımda, nitelik veya nicelik verilere öncelik verilebilir (Hanson vd., 2005). Bu çalışmada, her iki veri biçimine de eşit öncelik verilmiştir.

Bu çalışmanın katılımcıları, Türkiye'de orta ölçekli bir devlet üniversitesinde öğrenim gören 23 dördüncü sınıf matematik öğretmen adayıdır (16 kadın ve 7 erkek). Bu öğrencilerin tamamı, sekizinci yarıyılda açılan "Bilim, Teknoloji ve Toplum" dersine seçmeli ders olarak almışlardır. Tüm öğretmen adayları, genel kültür derslerini, pedagoji derslerini ve fizik gibi temel bilim derslerini tamamlamışlardır. Ayrıca çalışmanın katılımcıları güz döneminde bir devlet okulunda Okul Deneyimi I dersini tamamlamışlardır ve veri toplama sırasında Okul Deneyimi II dersine devam etmişlerdir. Tüm öğretmen adayları okul deneyimleri sırasında matematik derslerini gözlemlediklerini, 11'i de ortaokul öğrencilerine matematik dersini, 3'ü fen bilgisi dersini özel ders olarak öğrettiklerini ifade etmişlerdir. Tüm öğretmen adayları gönüllü olarak çalışmaya katılmıştır.

Öğretmen adaylarının kişisel matematik öğretimi öz-yeterlik inançlarında ve matematik öğretimi sonuç beklentisi inançlarında herhangi bir fark olup olmadığını görmek için Matematik Öğretimine Yönelik Öz Yeterlik İnanışları (MTEBI) ölçeği (Çakıroğlu, 2008) kullanılarak nicel veriler toplanmıştır. Çalışmanın nitel verileri ise araştırmacılar tarafından geliştirilen açık uçlu sorularla toplamıştır.

Nicel verilerin analizinde eşleştirilmiş örneklem t-testi kullanılmıştır. Nitel veriler ise içerik analizi yoluyla analiz edilmiştir.

Sonuç ve Tartışma

İlk araştırma sorusu, bütünleşik STEM öğretiminin öğretmen adaylarının matematik öğretimi öz-yeterlik düzeyleri üzerindeki etkililiğini araştırmak için tasarlanmıştır. Sonuçlar, bütünleşik STEM öğretiminin, matematik öğretmen adaylarının kişisel matematik öğretimi öz-yeterlik inançlarını (PMTE) geliştirdiğini, göstermektedir. Benzer bir şekilde, öğretmen adaylarının sonuç beklentisi inançları, STEM temelli öğretim sonrası gelişmiştir. Bu sonuçlar üç farklı şekilde yorumlanmıştır: Bu çalışmada öğretmen adayları matematik ve fen arasındaki ilişkiyi STEM temelli öğretimle anlamış olabilir, bu nedenle öz-yeterlikleri önemli ölçüde artmış olabilir. Zira Sanders'a (2009) göre fen ve matematiği birlikte öğretmek öz-yeterlik inançlarını geliştirebilir. Başka bir olası yorum, öğretmen adaylarının STEM tabanlı öğretim sırasında kazandığı deneyimleridir. Zira Bandura'ya (1986) göre, öz-yeterlik kaynaklarından biri, yetenek göstergesi olarak hizmet eden etkin ustalık deneyimleridir. Buna dayanarak öğretmen adaylarının ustalık deneyimlerinin, dolaylı öğrenme deneyimlerinin ve başarılı performans duygularının öğretmen adaylarının öz yeterlik inançlarını artırabileceğine inanıyoruz. Ancak, öğretmen adaylarının öz yeterliliklerindeki artışı sadece STEM temelli eğitimden kaynaklandığı şeklinde yorumlamak zordur. Bu artışın bir başka olası yorumu da bu seçmeli derste öğretmen adaylarına sağlanan mentorluk olabilir. Zira literatürde mentorluğun, duygusal destek ve rehberlik sağlayarak akademik başarıyı etkilediği ve katılımcıların güven düzeylerini geliştirdiği bildirilmektedir (Liang vd., 2002).

İkinci araştırma sorusu, öğretmen adaylarının bir dönem süren STEM eğitiminden sonra STEM entegrasyonu hakkındaki görüşlerini araştırmak için tasarlanmıştır. Bu nedenle, nitel veriler aracılığıyla öğretmen adaylarının öğretimden sonra öz-yeterlik inançlarındaki değişim araştırılmıştır. Tüm öğretmen adayları uygulama öncesinde, bütünleşik STEM öğretimi için kendilerini kısmen yeterli hissettiklerini belirtirken, uygulama sonrasında bu görüşleri değişmiştir. Uygulama sonrasında daha fazla öğretmen adayı, STEM disiplinlerini entegre etme konusunda kendilerini yetkin hissettiklerini ifade etmişlerdir. Bu bulgu, öğretmen adaylarının ustalık deneyimleri, dolaylı deneyimleri ve psikolojik tepkilerinin yanı sıra dersin eğitmeni ve matematik eğitimi uzmanı tarafından sağlanan mentorluğun öz-yeterlik inançlarını geliştirmelerine yardımcı olabileceği şeklindeki önceki yorumumuzu destekler niteliktedir.

Üçüncü araştırma sorusu, öğretmen adaylarının -özellikle matematik eğitiminde- bütünleşik STEM disiplinlerini öğretmeye yönelik öz yeterlilikleri hakkındaki görüşlerini araştırmak için tasarlanmıştır. Bu nedenle, öğretmen adaylarının matematiğin diğer disiplinlerle nasıl bağlantılı olduğu hakkındaki görüşleri araştırılmıştır. Sonuçlar, katılımcıların STEM temelli öğretimden önce matematik ve diğer disiplinler arasındaki bağlantının tam olarak farkında olmadığını göstermiştir. Katılımcılar, uygulama öncesinde, matematiğin sadece fen bilgisi dersi ile bütünleştirilebileceğini ifade etmişlerdir. Ancak bu görüşleri uygulama sonrasında değişmiştir. Katılımcıların tamamı matematiğin diğer disiplinlerle bütünleştirilebileceğini belirtmişlerdir. İlgili alan yazın bunun nedenini, tüm STEM disiplinlerinin izole dersler olarak öğretilme eğiliminde olması şeklinde açıklamaktadır (Blackley & Howell, 2015). Bunu destekleyen English (2016), STEM disiplinlerine dengeli bir şekilde odaklanmayı savunmaktadır.

Öneriler

Bu çalışmada sunulan sonuçlar, matematik öğretmeni adaylarından toplanan verileri ve onların STEM eğitiminin uygulanabilirliği hakkındaki düşüncelerini içermektedir Önceki bölümlerde tartışıldığı gibi birçok çalışmada bütünleşik STEM eğitimine yönelik çalışmalarda, matematiğe yeterince değer verilmediği ve araştırılmadığı belirlendiği için bu bağlamda, araştırmacılara önemli bilgiler sağlayabilir. Çalışmada elde edilen sonuçlar, aynı zamanda matematik eğitimcilerine STEM öğretimde karşılaşılan güçlükler konusunda yol gösterici olabilir. Bu bağlamda, öğretmenler ve program hazırlayanlar bu çalışmadan elde edilen sonuçlara göre eğitim konularını ve etkinlikleri dikkate alabilirler. Ancak bu çalışma sadece matematik öğretmen adaylarının matematik öğretimi özyeterlilik inanışlarının gelişimine ve STEM entegrasyonuna yönelik görüşlerine odaklanmıştır. Dolayısıyla farklı disiplinlerdeki öğretmen adaylarını (örneğin fen ve matematik) içeren karşılaştırmalı bir çalışmanın yürütülmesi, farklı disiplinlerin bilgilerinin aynı STEM temelli öğretimi nasıl desteklediğine dair fikir verebileceği düşünülmektedir.

Etik Kurul İzin Bilgileri

Araştırmanın etik kurul izni, Uşak Üniversitesi Sosyal ve Beşeri Bilimler Bilimsel Araştırma ve Yayın Etiği Kurulu tarafından 13.01.2022 tarih ve 2022-25 sayılı kararı ile alınmıştır.

Araştırmanın Etik Taahhüt Metni

Yapılan bu çalışmada bilimsel, etik ve alıntı kurallarına uyulduğu; toplanan veriler üzerinde herhangi bir tahrifatın yapılmadığı, karşılaşılacak tüm etik ihlallerde "Cumhuriyet Uluslararası Eğitim Dergisi ve Editörünün" hiçbir sorumluluğunun olmadığı, tüm sorumluluğun Sorumlu Yazara ait olduğu ve bu çalışmanın herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiş olduğu sorumlu yazar tarafından taahhüt edilmiştir.

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