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ORIGINAL ARTICLE

Examining the Mediating Role of STEM Attitudes between STEM Pedagogical Content Knowledge and STEM Intra Class Practice Self-Efficacy

Pınar Çavaş[1], Ahmet Kara[2], Şengül S. Anagün[3], Aslıhan Ayar[1]

[1]Department of Elementary Education, Faculty of Education, Ege University, Turkiye, [2]Department of Developmental Psychology, Faculty of Arts and Science, Kastamonu University, Turkiye, [3]Department of Elementary Education, Faculty of Education, Eskisehir Osmangazi University, Turkiye

***Corresponding Author:** aslihanayar96@gmail.com

ABSTRACT

The general purpose of this research is to examine the mediating effect of STEM attitudes between STEM pedagogical content knowledge (CK) and STEM intra-class practice self-efficacy. This research was conducted in a causal design. A total of 345 teacher candidates, 261 females (75.7%) and 84 males (24.3%), were included in the research. The data were collected with the STEM Pedagogical CK Scale (STEM), Attitude Scale for STEM Education (STEMAS), and STEM Intra Class Practice Self-Efficacy Perceptions Scale. Path analysis technique was used in data analysis. In addition, bootstrapping analysis was used to evaluate the significance of the mediating effect of STEM attitudes. At this point, 1000 resamples were made and lower-upper bound confidence intervals were determined. In research results, the mediating effect of STEM Attitudes was found to be significant in the relationship between STEM Pedagogical CK and STEM Intra Class Practice self-efficacy.

KEY WORDS: Path analysis; STEM attitudes; STEM intra-class practice self-efficacy; STEM pedagogical content knowledge

INTRODUCTION

In a rapidly changing world, lifelong learning emerges as one of the important ways for individuals to keep up with the developments in daily and business life. Education systems are also forced to adapt to these developments and integrate these changes to their own systems. In the 21st century, also called the age of technology, interest in STEM fields has become the focus of education systems. In this context, integrated STEM education is gaining increasing popularity all over the world (Song, 2020). Many researchers define STEM education as a multidisciplinary approach that brings together four different disciplines such as science, technology, engineering, and mathematics, and offers students unique learning experiences to solve real-world problems, thus establishing connections between school, society, business life, and the global world (Bybee, 2013; Tsupros et al., 2009; Vasquez et al., 2013). The goal of STEM education is for students to have STEM literacy (English, 2016; Morrison, 2006; National Research Council, 2011). STEM-based education emphasizes the importance of providing education to develop 21st century skills such as decision-making, leadership, teamwork, and process management, which are necessary for social and professional life. Teachers have a crucial role in the integration of STEM approach to classroom implementations. Reeve (2015) argued that a teacher in an integrated STEM classroom should be a "STEM Thinker" who knows and takes into account the connection of STEM-related concepts, principles, and practices with the products we use in our daily lives. In addition, Reeve (2015) defined "STEM Thinkers" as "teachers who apply STEM subjects in the real world and organize inquiry-based learning activities for their students" (p. 9). Pryor and Kang (2013) also supported similar views and stated that through STEM education, students can develop relationship-building skills that will enable them to apply their knowledge to new situations. The success of STEM education is closely related to teacher competencies. In order for teachers to implement successful STEM education in their classrooms, it is important for teachers to have knowledge, awareness, attitude, openness to change and self-efficacy perception about STEM. By examining the relevant literature, Song (2020) identified three areas of competencies that teachers must have for the successful implementation of integrated STEM education. These are cognitive characteristics (CC), teaching Instructional skills (IS), and affective characteristics (AC).

1. CC of teacher competence: Subject knowledge, pedagogical knowledge, curriculum knowledge, ability to plan and implement lessons, understanding the student and the nature of learning, establishing interdisciplinary connections, interdisciplinary; interdisciplinary skills, flexibility; creativity; innovation
2. IS of teacher competency; student-centered learning, problem solving with unique local and global problems and daily life, teaching strategies, assessment, providing feedback, collaboration, and technological skills

3. AC of teacher competency: communication, enthusiasm passion, empathy, professionalism, self-efficacy, and believing that all students can learn (Song, 2020).

Shulman's (1987) approach to teachers' knowledge structure has been widely accepted. According to this approach, teachers should have subject matter content knowledge (CK), pedagogical content knowledge (PCK), curricular knowledge, knowledge of learners, knowledge of educational context, and knowledge of the philosophical and historical aims of education. Shulman explained that CK points out the amount and organization of knowledge in the teacher's mind. Teachers should not be able to define accepted truths for students in just one field. They must also be able to explain the reasons for a particular proposition and how it relates to other propositions within and outside the discipline, both in theory and practice (Shulman, 1986).

Pedagogical knowledge encompasses subjects such as classroom management, teaching methods, and classroom environment and is related to teaching (Richardson, 1996). A teacher who will realize STEM education should have STEM education field knowledge, pedagogy knowledge, and the skills required by the 21st century. At the same time, it is important to integrate these into their lessons and use them actively (Hudson et al., 2015). Teachers' specialized CK is a major determinant of students' success. Teachers with strong STEMPCK can effectively teach STEM subjects and easily integrate STEM disciplines into the classroom (Ball et al., 2008; Wang et al., 2011). Teachers' mastery of the subjects they will teach students also affects their self-efficacy in the teaching-learning process (Stohlmann et al., 2012).

Self-efficacy is the conviction that one can accomplish tasks or influence circumstances that affect one's life (Bandura, 1986). Teachers' beliefs, behaviors, performance, and self-efficacy related to teaching and learning influence their practices (Davis et al., 2006). To teach STEM effectively and healthily, teachers need competence in STEM pedagogical CK (Schmidt, 2011; Shulman, 1986) and self-efficacy in teaching the content (Tschannen-Moran and Hoy, 2001). Teachers with this sense of efficacy also have higher organizational tendencies and planning skills (Allinder, 1994).

For qualified STEM education, more than the subject knowledge and expertise of the teacher in STEM disciplines will be required. The teacher should also have self-efficacy for STEM practices, which can apply STEM education in the classroom, deepen their students' knowledge, and develop STEM awareness and understanding, in parallel with general teacher self-efficacy. Factors such as classroom resources, teacher professional development (PD), and teachers' self-efficacy beliefs influence how teachers effectively implement STEM education in the classroom (Davis et al., 2006; Menon and Sadler, 2016). Consequently, teachers' efficacy beliefs about STEM education are of great importance for the success of STEM education (Brand and Wilkins, 2007; Zeldin et al., 2008).

It is necessary to determine the beliefs that teachers have to improve their STEM teaching capacity and the possible impact of these beliefs on STEM education. Attitudes and beliefs are important concepts in understanding teachers' thought processes, classroom practices, change, and learning to teach. Attitudes are strongly influenced by teachers' experiences both during the profession and as students and what and how they learn (Richardson, 1996).

Ajzen and Fishbein (2005) talk about two types of attitudes. These are (1) general attitudes referring to broad, general objects, groups, or goals (e.g., STEM) and (2) attitudes toward behavior referring to the performance of specific behaviors related to an object or goal (e.g., teaching STEM). Teachers' attitudes toward STEM fields reveal their feelings, state of mind, and views that they may have with respect to teaching STEM disciplines within the classroom setting (Thibaut et al., 2018; van Aalderen-Smeets et al., 2012).

Al-Salami et. al. (2017) state that to increase students' perceptions and interest in STEM, teachers should develop positive attitudes toward teaching STEM, positive attitudes towards collaboration with other teachers, and a desire to change existing teaching strategies. Besides, according to Margot and Kettler (2019), teachers who believe they can teach STEM subjects are more willing to use STEM curricula. For STEM education to be effective, teachers need to be prepared to successfully implement current pedagogical approaches in their classrooms. Some researchers (Kagan, 1992; van Aalderen-Smeets et al., 2015) emphasize that PD and teacher education programs shape teachers' attitudes. For this reason, the need to access teacher education programs and PD opportunities for teachers and pre-service teachers cannot be overemphasized. It is thought that to achieve an effective STEM education, teachers should have knowledge of STEM education content, a positive attitude toward teaching STEM, and self-efficacy belief. This research examined the mediating effect of STEM attitudes between STEM pedagogical CK and STEM intra-class practice self-efficacy. The results of the research will guide researchers working in the field of developing STEM practices and improving teachers' STEM teaching.

The following hypotheses were predicted within the scope of the research:

- H^1: Higher levels of STEM pedagogical CK will predict more positive STEM attitudes
- H^2: Higher levels of STEM attitudes and more positive STEM intra-class practice self-efficacy
- H^3: Higher levels of STEM pedagogical CK will predict more positive STEM intra-class practice self-efficacy
- H^4: STEM attitudes will mediate the relation between STEM pedagogical CK and STEM intra-class practice self-efficacy is significant.

METHODS

Research Model

The general purpose of this research is to examine the mediating effect of STEM attitudes between STEM pedagogical CK and STEM intra-class practice self-efficacy. In line with this general purpose, this research was conducted in a causal design. In the causal design, the research is designed by establishing a cause-effect relationship between the variables (Neuman, 2007). This research constructed STEM pedagogical CK as cause variable, STEM attitudes as the mediator variable, and STEM intra-class practice self-efficacy as the outcome variable. The Hypothetical Model of the research is presented in Figure 1.

Research Group

Research data were collected voluntarily from pre-service teachers studying at state universities in different regions of Turkiye. In the research, extreme value analysis was performed before starting the path analysis. The data of 4 participants were excluded from the analysis because they were outliers. A total of 345 teacher candidates, 261 female (75.7%) and 84 male (24.3%), were included in the analysis. The universities where the participants studied are distributed in Central Anatolia (47.8%), Aegean (24.6%), Eastern Anatolia (16.2%), Marmara (14.5%), and Black Sea (0.9%). The branch distribution of these 345 pre-service teachers consists of 245 primary teachers (71.0%) and 100 science teachers (29.0). In addition, the class levels of the participants are 224 people in the 3rd grade (64.9%) and 121 people in the 4th grade (35.1%) (Table 1).

Table 1: General characteristics of research group

Features	n	%
Regions		
Central Anatolia	151	47.8
Aegean	85	24.6
Eastern Anatolia	56	16.2
Marmara	50	14.5
Black Sea	3	0.9
Gender		
Female	261	75.7
Male	84	24.7
Department		
Primary school teacher cand	245	71.0
Science teacher cand	100	29.0
Grade Level		
3rd grade	224	64.9
4th grade	121	35.1
Total	345	100

Instruments

STEM pedagogical content knowledge scale (STEM-PCK)

STEM-PCK scale was developed by Akçay and Avcı (2022) to measure pre-service teachers' the Pedagogical CK toward STEM education. STEM-PCK scale consists of 57 items and five factors in 5-point Likert type. The dimensions of the scale are *STEM Pedagogical Knowledge (STEM Knowledge for Teaching)*, *Pedagogical Knowledge*, *Engineering Pedagogical Knowledge*, *Mathematics Pedagogical Knowledge*, *Science Pedagogical Knowledge*. Since the path analysis technique was used in this research, the total score of the scale was included in the analysis process. In the confirmatory factor analysis conducted by Akçay and Avcı (2022) for STEM-PCK, the goodness of fit values *(CFI= 0.96, NFI= 0.94, RFI= 0.94, and RMSEA= 0.07*) were found to be acceptable. The reliability values were calculated as 0.98 for internal consistency reliability value and the test-retest reliability was 0.97 for total scale. The internal consistency reliability coefficient of STEM-PCK among the sub-dimensions ranged between 0.89 and 0.98 (Akçay and Avcı, 2022). In this research, the internal consistency coefficient for the reliability of STEM-PCK was calculated as 0.99. Some items for the STEM-PCK scale are presented in Table 2.

Table 2: Sample Items from STEM-PCK

Factors	Items
Pedagogical Knowledge	Q46. I can use different teaching methods to help students think creatively.
	Q50. I know how to organize classroom management
Science Pedagogical Knowledge	Q13. I can explain why any topic in science is important.
	Q19. I know how to choose effective learning approaches to ensure that students learn science concepts meaningfully.
Mathematics Pedagogical Knowledge	Q3. I can explain math concepts.
	Q16. I can easily use updated scientific knowledge in mathematics whenever I need it.
Engineering Pedagogical Knowledge	Q10. I can give various examples of the applications of engineering in daily life.
	Q23. When teaching engineering concepts, I can relate them to other disciplines.
STEM Pedagogical Knowledge (STEM Knowledge for Teaching)	Q1. I can research/investigate the necessary knowledge of STEM subjects.
	Q30. I know that different teaching approaches are required for STEM activities in different subjects.

Attitude Scale for STEM education (STEMAS)

STEMAS was developed, and its validity and reliability analysis was performed by Yaman (2020). STEMAS includes 17 items and a one-dimensional structure. In the confirmatory factor analysis conducted by Yaman (2020) for STEMAS, the goodness of fit values *(CFI = 0.99, NFI = 0.98, GFI = 0.88, AGFI = 0.84 and RMSEA = 0.07)* were calculated to be at an acceptable level. It was found as 0.97 in the internal consistency reliability analysis performed by Yaman (2020). In this research, the internal consistency coefficient value of STEMAS was obtained as 0.98. Sample items related to the STEMAS are presented in Table 3.

STEM intra class practice self-efficacy perceptions scale (STEMICPSEPS)

STEMICPSEPS was developed, a validity and reliability studies were also carried out by Yaman (2020). STEMICPSEPS consists of 23 items and three dimensions. Since the path analysis technique was applied in this research, the total score of the scale was taken and analyzed. In the confirmatory factor analysis conducted by Yaman (2020) for STEMICPSEPS, the goodness of fit values *(CFI = 0.98, NFI = 0.97, GFI = 0.83, AGFI = 0.80 and RMSEA = 0.07)* were found to be acceptable. The internal consistency coefficient made by Yaman (2020)

Table 3: Sample items from STEMAS

Items
Q4. I think that with STEM education, students' 21st century skills (communication, collaboration, critical thinking, creativity, etc.) will develop.
Q11. I believe that students will gain original ideas through STEM education.
Q16. I believe that students' problem-solving skills will improve with STEM education.

within the scope of reliability analysis for the whole scale was determined as 0.96. In this research, the internal consistency coefficient of STEMICPSEPS was found to be 0.96. Sample items for the STEMICPSEPS are presented in Table 4.

Data Analysis

In this research, first, a preliminary analysis was made. For this, normality (kurtosis and skewness) and multicollinearity (VIF, tolerance, and conditional index) values were examined (Finney and Distefano, 2006; Kline, 2019). In addition, in this research, the path analysis technique was used to reveal the cause-effect relationship between observed variables such as STEM attitudes, STEM pedagogical CK, and STEM intra-class practice self-efficacy (Kline, 2019). In addition, the goodness of fit values ($\chi2$/df, CFI, RMSEA, GFI, and AGFI) used in this research were evaluated according to the criteria proposed by Schermelleh-Engel et al. (2003). In addition, bootstrapping analysis was used to evaluate the significance of the mediating effect of STEM attitudes. At this point, 1000 resamples were made and lower-upper bound confidence intervals were determined. The fact that these confidence intervals do not contain zero indicates that the mediating effect of STEM attitudes is significant in this research (Shrout and Bolger, 2002) .

RESULTS

Preliminary Analysis

In this research, preliminary analysis findings were evaluated according to normality (kurtosis and skewness) and multicollinearity (VIF, tolerance, and conditional index) values. In this research, kurtosis values were found to vary between −0.12 and 1.58. Skewness values were observed that varied between −1.50 and −0.63 (Table 5). These values prove that this research meets the normality assumption (Finney and Distefano, 2006). In this research, VIF 1.29; tolerance 0.77, and conditional index values were found to vary between 1.00 and 10.11. These findings prove that this research does not have a multicollinearity problem (Kline, 2019).

In this research, it was determined that there was a significant and positive relationship between STEM Pedagogical CK and STEM Attitudes ($r = 0.477$; $p < 0.01$). In addition, a significant and positive correlation was found between STEM Attitudes and STEM Intra Class Practice Self-Efficacy ($r = 0.151$; $p < 0.01$). On the other hand, it was observed that there was no significant relationship between STEM Pedagogical CK

Table 4: Sample items from STEMICPSEPS

Factors	Items
Creating a Learning Environment	Q3. I can encourage students to ask questions that are geared toward critical thinking.
	Q8. I can help my students develop sensitivity to the problems around them.
STEM Integration	Q10. I can design activities that can give my students 21st-century skills.
	Q14. I can design course activities by integrating STEM disciplines.
Establishing a Real-Life Context	Q19. I can design lesson plans according to real-life problems.
	Q23. I can support my students in carrying out projects to solve a problem.

Table 5: Descriptive statistics

Variables	SD	Skewness	Kurtosis
STEMPCK	56.54	−0.79	−0.12
STEMA	17.37	−1.50	1.58
STEMICPSE	12.66	−0.63	1.49

STEMPCK: STEM pedagogical content knowledge, STEMA: STEM Attitudes, STEMICPSE: STEM Intra-class practice self-efficacy

Table 6: Correlations

Variables	1	2	3
1-STEMPCK	1		
2-STEMA	0.477**	1	
3-STEMICPSE	0.103	0.151**	1

**p<0.01, STEMPCK: STEM pedagogical content knowledge, STEMA: STEM Attitudes, STEMICPSE: STEM intra-class practice self-efficacy

and STEM Intra Class Practice Self- Efficacy ($r = 0.103$; $p > 0.05$) These findings are also presented in Table 6.

Path Analysis

In this research, the path analysis technique was used to reveal the cause-effect relationship between observed variables such as STEM attitudes, STEM pedagogical CK, and STEM intra-class practice self-efficacy. Path analysis findings of the hypothetical model are presented in Figure 2 and Table 7.

When Figure 2 and Table 7 are examined, a one-unit increase in STEM Pedagogical CK increases STEM Attitudes by 0.48 ($t = 10.053$; $p < 0.001$). Also, a one-unit increase in STEM Attitudes increases STEM Intra Class Practice Self-Efficacy by 0.13 ($t = 2.192$; $p < 0.05$). On the other hand, it was found that the coefficient of path from STEM Pedagogical CK to STEM Intra Class Practice Self-Efficacy was insignificant ($t = 0.647$; $p > 0.05$). This meaningless path was removed from the model and reanalyzed. The standardized path coefficients of the final model are shown in Figure 3 and the path analysis results are shown in Table 8.

As shown in Figure 3 and Table 8, a one-unit increase in STEM Pedagogical CK increases STEM Attitudes by 0.48 ($t = 10.053$; $p < 0.001$). In addition, a one-unit increase in STEM Attitudes

Table 7: Path analysis results of the hypothetical model

Dependent variable		Independent variable	Estimate	S.E.	C.R.	p-value
STEMA	<---	STEMPCK	0.146	0.015	10.053	***
STEMICPSE	<---	STEMA	0.097	0.044	2.192	0.028*
STEMICPSE	<---	STEMPCK	0.009	0.014	0.647	0.517

***p<0.001; **p<0.01; *p<0.05, STEMPCK: STEM pedagogical content knowledge, STEMA: STEM attitudes, STEMICPSE: STEM intra-class practice self-efficacy

Table 8: Path analysis results of the final model

Dependent Variable		Independent Variable	Estimate	S.E.	C.R.	p-value
STEMA	<---	STEMPCK	0.146	0.015	10.053	***
STEMICPSE	<---	STEMA	0.110	0.039	2.842	0.004**

***p<0.001; **p<0.01; *p<0.05, STEMPCK: STEM pedagogical content knowledge, STEMA: STEM attitudes, STEMICPSE: STEM intra-class practice self-efficacy

Table 9: Goodness of fit indices of the final model

Goodness of fit indices	Fit criteria	Values of the model	State of the fit
χ^2/df	0≤ χ^2/df≤2	0.41	Good fit
CFI	0.97≤CFI≤1.00	1.00	Good fit
RMSEA	0≤RMSEA≤0.05	0.00	Good fit
GFI	0.95≤GFI≤1.00	0.99	Good fit
AGFI	0.90≤AGFI≤1.00	0.99	Good fit
NFI	0.95≤NFI≤1.00	0.99	Good fit

Source: Schermelleh-Engel et al. (2003)

Table 10: Bootstrap test results for STEM attitudes

Model pathway	Bootstrap values		Bias %95 CI	
	(β)	SE	Lower	Upper
Indirect effect				
STEMPCK→STEMA →STEMICPSE	0.07	0.02	0.021	0.123

Bootstrap is based on 1000 resamples (Hayes, 2017). β=Standardized coefficients. SE: Standard error, *p<0.05. STEMPCK: STEM pedagogical content knowledge, STEMA: STEM attitudes, STEMICPSE: STEM intra-class practice self-efficacy

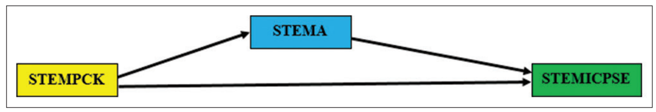

Figure 1: Hypothetical model. STEMPCK: STEM Pedagogical Content Knowledge, STEMA: STEM Attitudes, STEMICPSE: STEM Intra class practice self-efficacy

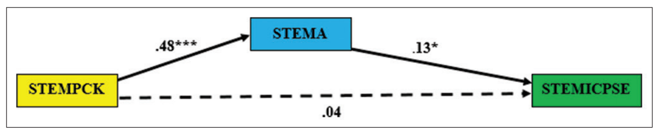

Figure 2: Standardized path coefficients of the hypothetical model. ***p<0.001; **p<0.01; *p<0.05, STEMPCK: STEM Pedagogical Content Knowledge, STEMA: STEM attitudes, STEMICPSE: STEM intra-class practice self-efficacy

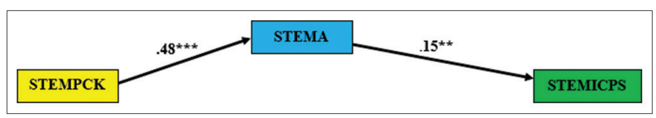

Figure 3: Standardized path coefficients of the final model. ***p<0.001; **p<0.01; *p<0.05, STEMPCK: STEM pedagogical content knowledge, STEMA: STEM attitudes, STEMICPSE: STEM intra-class practice self-efficacy

increases STEM Intra Class Practice Self-Efficacy by 0.15 (t = 2.842; p < 0.01). In addition to these, the goodness of fit values of the final model is presented in Table 9.

Significance of the mediation of STEM attitudes-(bootstrapping analysis)

The general purpose of this research is to examine the mediating effect of STEM attitudes between STEM pedagogical CK and STEM intra-class practice self-efficacy. For this purpose, bootstrapping analysis was used to test the significance of the mediating effect of STEM Attitudes. Analysis findings are given in Table 10.

Table 10 contains the findings regarding the significance of the mediating effect of STEM Attitudes. Accordingly, the mediating effect of STEM Attitudes was found to be significant in the relationship between STEM Pedagogical CK and STEM Intra Class Practice Self-Efficacy (β = 0.07, 95% CI = 0.021, 0.123). All these findings prove that STEM Attitudes have a significant mediating effect in the relationship between STEM Pedagogical CK and STEM Intra Class Practice Self-Efficacy.

DISCUSSION AND CONCLUSION

This research was conducted for the purpose of examining the mediating effect of STEM attitudes between STEM pedagogical CK and STEM intra-class practice self-efficacy using quantitative method. It constructed a hypothetical model to explore the structural effects of teachers' attitudes, pedagogical CK and intra class practice self-efficacy in teaching STEM. The data was collected from 345 science and primary school teacher candidates with STEM PCK Scale, Attitude Scale for STEM Education, and STEM ICPSEPS. The results of this research, which was carried out with the thought that it will guide researchers working in the field of improving STEM practices and improving teachers' STEM teaching, are important. Research results revealed that the mediating effect of STEM Attitudes was significant in the relationship between STEM Pedagogical CK and STEM Intra Class Practice Self-Efficacy. According to Song's (2020) teacher competency model teachers should have cognitive, instructional, and affective competencies for teaching STEM subjects. This research is based on this model.

This research's first hypothesis was teachers' higher levels of STEM pedagogical CK will predict more positive STEM attitudes. According to research results, it was determined that there was a significant and positive relationship between STEM Pedagogical CK and STEM Attitudes. Similarly, the study by Shidiq and Faikhamta (2020) found that teachers who had content and pedagogical knowledge about integrated STEM had positive attitudes, and there was a strong correlation between each other. Wahono and Chang (2018) also state that science teachers who have more knowledge about STEM subjects have a positive attitude toward STEM. Research results also accepted the second hypothesis assumption which is a one-unit increase in STEM Attitudes increases STEM Intra Class Practice Self-Efficacy. Contrary to this result, Hsu et al. (2011) found in their study that primary school teachers believed in the importance of STEM, but did not feel competent in teaching. Cunningham et al. (2006) state that the majority of teachers are not competent in teaching STEM, regardless of their background and teaching experience. Teachers' characteristics, perceptions, and attitudes related to STEM influence teachers' implementation of STEM approaches. The CK that teachers have is effective in their teaching self-efficacy (Rohaan et al., 2012). Teachers' AC such as attitudes and self-efficacy are as important a variable as their ability to apply knowledge and innovations. Teachers should have basic knowledge, skills, and tendencies that will effectively integrate STEM disciplines into their teaching to prepare qualified students of the 21st century for the digital age (Yıldız et al., 2019; Lin and Williams, 2016). In addition, teacher attitudes and behavioral intentions (Lin and Williams, 2016), teaching practices (Bandura, 1986; Thibaut et al., 2018), and teaching decisions (Pajares, 1992) are interrelated factors. Research result reveals the necessity of providing teachers with opportunities for pedagogical approaches to STEM education in pre-service and in-service teacher training (Rinke et al, 2016). Research has shown that when teachers participate in hands-on STEM learning experiences, they develop increased confidence and self-efficacy regarding this subject (Cantrell et al., 2003; Bleicher, 2007). As stated by Bursal and Paznokas (2006), prospective teachers' attitudes toward STEM subjects affect their attitudes toward teaching these subjects and how they will teach these courses in the future. The fact that teachers who design and implement the entire learning process have pedagogical CK about STEM and positive STEM attitudes will support them in teaching STEM disciplines to their students effectively. In this way, students will be able to learn science, mathematics, technology, and engineering terms and find solutions to real-life problems. Similar to our research results, Yaman (2020) determined that there is a correlation between teachers' attitudes towards STEM education and their in-class practice self-efficacy perceptions. Furthermore, Sias et al. (2017) revealed in their research that teachers' pedagogical competencies and their ability to employ innovative learning strategies are the most important factors affecting the success of STEM teaching.

Research results also indicate that STEM attitudes will mediate the relationship between STEM pedagogical CK and STEM intra-class practice self-efficacy is significantly. A strong sense of efficacy enhances an individual's sense of accomplishment (Bandura, 1997). Self-efficacy in STEM teaching practices for teachers is an important role for appropriate implementations of STEM disciplines. Attitudes toward STEM support to see what teachers are thinking and feeling about STEM implementations (Wahono and Chang, 2019) and help to determine best teaching practices in STEM education (Chia and Maat, 2018). Gardner et al. (2019) revealed in their research that teachers improved in their self-efficacy and made productive changes in their classroom practices after attending a PD program. According to the findings of this study, it can be suggested that to enhance teachers' engagement in STEM teaching, future research may focus on the arrangement of professional programs for teachers. In Turkiye, studies aimed at improving the integrated teaching knowledge of teachers are not sufficient. For this reason, PD programs, courses, and practices that support integrated teaching STEM knowledge should be included in field teaching programs and communication and collaboration opportunities should be created for teachers and teacher candidates.

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