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An Analyses and Meta-Synthesis of Research on STEM Education

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Abstract
The purpose of the current study is to draw an outline of empirical research studies conducted on STEM education with a focus on student achievement, in addition to their creativity and problem solving skills, attitudes and interests towards STEM subjects. After an initial screening of several articles, papers and dissertations on STEM education, 33 studies are selected according to their fit into our research framework. These selected studies are exposed to analysis and synthesis processes in line with the stages of meta-synthesis research method to specify and present findings under the specified themes. The findings include the strong alignment between STEM education principles and international comparison studies, such as PISA/TIMSS, as well as a positive impact of STEM education on student achievement at school and on their attitudes towards individual STEM disciplines. There is also evidence to support that interventions that follow STEM education principles reinforce students' problem solving and creativity.
Keywords: STEM education, meta-synthesis studies, science and mathematics education

1. Introduction

Development in science in recent years increased the need for individuals who are well-equipped in their fields and who can add innovation to their expertise. Infact, 21st century economies needed such individuals with expert competence in their own fields with a good understanding of other Science, Technology, Engineering and Mathematics (STEM) disciplines. Although the need for individuals with sufficient knowledge in these areas increased, current education system fell short at this point to raise such people (Yıldırım & Selvi, 2015). Besides, Quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future success of students (Stohlmann, Moore & Roehring, 2012). For all these reasons, many countries tried and are still seeking to improve quality of the education given in subjects such as science, technology engineering and mathematics (Yıldırım & Selvi, 2015).

Although the STEM acronym is coined up as the first letters of Science, Technology, Engineering and Mathematics (Jayarajah, Saat & Abdul Rauf, 2014), several researchers believed that STEM covers a larger and more comprehensive understanding than these individual disciplines. For example, some researchers claimed that STEM education included the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area (Corlu, Capraro & Capraro, 2014). According to Meng, Idris and Eu (2014) STEM education should be understood as an interdisciplinary approach with a strong emphasis on community created by those who conduct it; either at the workplace by scientists or at the school level; either by teachers working together or by students working on interdisciplinary projects (Corlu, 2014). On the other hand, some other researchers claimed that there was no standard definition for STEM education and different interpretations were possible (Longdon et al., 2011; Koonce, Zhou and Anderson, Hening and Conley, 2011; Zhou, 2010).

STEM education includes the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area (Corlu, Capraro & Capraro, 2014). The word "science", the first letter of which formed one of the letters in the abbreviation "STEM", contains a more comprehensive meaning than science (Yıldırım & Altun, 2014). Science had a broader meaning including all disciplines and STEM has a broader meaning which includes not only physics, biology, chemistry, engineering and computer engineering but also behavioral sciences (psychology) and social sciences (Breckler, 2007; Green, 2007). Although, legislative efforts to improve STEM education focus on STEM fields, which consist of natural sciences (biology, physics, chemistry et al.), technology, engineering, and mathematics (Kuenzi, 2008). STEM education should be able to provide wider opportunities for students to develop their competencies in not only Science, but also Technology, Engineering and Mathematics and its related areas (Osman & Saat, 2014).

STEM education is an interdisciplinary area of study that bridges the four disciplines of science, technology, engineering, and mathematics. STEM gets it philosophy from four important basic disciplines (Meng, Idris & Eu, 2014). STEM rose with the power it took from these four basic disciplines. Knowledge that is obtained since the emergence of STEM was revealed under the light of these disciplines. All these disciplines were developed by being filtered through education. According to STEM the main goal of education is to prepare a person for life and ensure that he lives competently (Moore et. al, 2014). A competent life is only possible with living an educated life.

Today STEM education in many countries, especially in countries like United States, Korea, China and UK focus on STEM philosophy. STEM philosophy ensures that countries, in which it is applied, maintains their

current economic and technological leaderships. On the other hand, it is also used to increase countries success in international examinations such as PISA and TIMSS. These examinations are considered as podiums on which counties put appearances. At this point, STEM has an important place for countries.

1.1. Purpose of the Study

The purpose of this study is to draw an outline of empirical research studies conducted on STEM education with a focus on student achievement, in addition to their creativity and problem solving skills, attitudes and interests towards STEM subjects. The following questions were tried to be answered within the framework of this purpose.

1. Does STEM Education influence students' academic success, attitudes and problem solving skills? If any, what kind of effect does it have?
2. Does STEM Education influence students' motivation and scientific process skills? If any, what kind of effect does it have?
3. What do Teachers think about STEM Education?

2. Holonic Manufacturing System (HMS)

2. Research Methodology

2.1 Study Design

"Meta-synthesis", which is a qualitative study design, was used in this study. Meta synthesis is a method which research studies and investigates the results of several studies and tries to interpret the data obtained as a result of this investigation (Finfgeld, 2003). According to Sondelowsky and Barrose, (2003), the main objective of meta synthesis is to interpret the studies that were investigated, ensure that a detailed interpretation is formed and to remain loyal to the interpretations of every study.

2.2 Collection of Data

Screening and selection processes were determined by the researchers in order to determine the studies to be included to the meta-synthesis study. The researcher firstly determined the search included using ERIC (EBSCO), ProQuest Digital Dissertations, JSTOR, Scopus, and Google Scholar which include the studies about STEM education, and used the studies published between 1996 and 2016 by start from these data resources. Field experts were consulted while determining the keywords and the researches made in this area were investigated and searching under the terms STEM Education, STEM, Integrative STEM Education, STEAM Education, STEAM, Science, Technology, Engineering, Mathematics. Research from approximately 70 studies articles was accumulated to write a larger review of STEM education. 34 articles reports and theses that might benefit the purpose Of the study were taken into the scope of the study as a result of the scan.

The measures determined for including and excluding the studies:

1. Whether or not they are studies in which the effect of STEM education was investigated
2. Whether or not they are conducted in primary, secondary or high schools
3. Whether or not they are articles, reports and theses
4. Whether or not the titles of articles, reports and theses include the keywords
5. Whether or not studies are national or international

2.3 Coding Method

Under the light of information obtained from articles, reports and theses, the themes were investigated according to qualitative and quantitative findings and codes Were formed in order to provide easy interpretations from analyses (See Table 1). Studies taken into the scope of this study was sorted according to features and their publication years and coded as “X1, X2, ...” for convenience. Interpretations and analyses were made according to this coding. (See Table 2).

Table 1. Codes of Meta-synthesis

Themes	Theme Contents
Academic Success	SAS- STEM’s Effect on Academic Success
Problem Solving	SPS-STEM’s Effect on Problem Solving
Creative Thinking	SCT-STEM’s Effect on Creative Thinking
Attitude	SA-STEM’s Effect on Attitude
Interest / Motivation	SIM-STEM’s Effect on Interest and Motivation
Scientific Process Skills	SSPS-STEM’s Effect on Scientific Process Skills
Teacher Views	STV-Teacher Views with regard to STEM
PISA and TIMSS	SPT-STEM and PISA and TIMSS exams

2.2.1 Studies included in Meta-synthesis

The code, author, publication year and type, method and theme code of each study included in this study are given in the following Table (see Table 2).

Table 2. The Studies found as a Result of Literature Review and their codes

Code	Author(s)	Year	Type of Publication	Method	The Measurement Tool Employed	Theme Code
X1	Shin, Y.J. & Han, S.K.	2013	Article	It is a qualitative study. 93 teachers took part in the study. Frequency and percentage were calculated.	Survey	STV SPT
X2	Kim, G.S. & Choi, S.Y.	2012	Article	It is a quantitative study. 38 people participated in the study. The experimental group included 18 individuals, while the control group included 20 people. The data was analyzed with t-test and ANOVA.	Survey Attitude	SPS SA
X3	Lee, J.W, Park, H.J. & Kim, J.B.	2013	Article	It is a qualitative study. 101 teachers took part in the study. Frequency and percentages were calculated.	Survey	STV SPT
X4	Park, S.J. & Yoo, P.K.	2013	Article	It is a quantitative study in which 52 people participated. 26 individuals were in the experimental group and 26 were in the control group. Data were analyzed with t-test and ANOVA.	Interest and motivation scale	SIM
X5	Elliott, B., Oty, K., Mcarthur, J & Clark, B.	2001	Article	It is a quantitative study. 211 students took part in the study. Attitude scale was used. Data were analyzed with Chi-square and t-test.	Glaser Critical Thinking Appraisal scale	SA SPS
X6	Judson, E.	2014	Article	It is a quantitative study. The students attending STEM focused schools and students attending schools that are not STEM focused were examined. To this end, four schools were chosen. Various numbers of students from these four schools participated the study; respectively 70, 53, 89 and 77 students. Data were analyzed with ANCOVA and t-test.	Success Test	SAS
X7	Şahin, S., Akbulut, B., Hascadan, B., Özgenol, Y. & Güley, A.	2014	Notification	It is a qualitative study. Pre-school teachers took part in it.	Observation and Survey	STV
X8	Olivarez, N.	2012	PhD Dissertation	It is a quantitative study. 176 people participated the study. 73 were in the experimental group and others made up the control group. The data collected were interpreted based on MANOVA and t-test results.	Success Test	SAS
X9	Erdoğan, N., Capraro, M.M., Capraro, R.M. & Öner, A.T.	2013	Notification	It is a quantitative study. 53 people took part in the study. The correlation between attitude and gender, and other elements was examined. Data were examined with t-test.	TOSRA scale (Test of Science Related Attitudes)	SA
X10	Seong-Hwan, C.	2013	Article	It is a quantitative study. 40 people took part in the study. 19 of them were in the experimental group while 21 are in the control group. The data were analyzed with t-test.	Attitude and interest scale	SA SIM
X11	Kim, D.H, Ko, D.G., Han, M.J. & Hong, S.H.	2014	Article	It is a quantitative study. 141 people took part in the study. While 69 of them were in the experimental group, 72 were in the control group. The data collected were interpreted based on t-test results.	Interest and Creativity Scale	SIM SCS
X12	Cotabish, A., Dailey, D. Robinson, A. & Hunghes, G.	2013	Article	It is a quantitative study. It was conducted on primary school students. Scientific Process Skills, Knowledge and concept knowledge of the students were measured. The data collected were interpreted based on t-test results.	Scientific Processing, Aptitude and Concept test	SAS SSPS
X13	Wang, H.H.	2012	PhD Dissertation	It is a qualitative study. 77 teachers participated in the study. The data collected were submitted to content analysis.	Interview form	STV

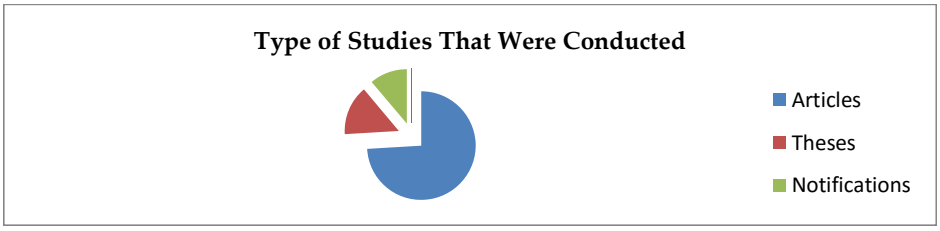
X14	Egli, S.	2012	Master Thesis	It is a qualitative study. 17 teachers took part in the study. The data were collected from only 11 of the teachers.	Interview form	STV
X15	Ross, J.A. & Gray, A.H.	2012	Article	It is a quantitative study. 53 teachers, 973 students took part in the study. Data were interpreted with based on ANOVA and t-test results.	Attitude and Motivation	SAS SIM SA
X16	Irwın, R.	2013	Research Paper	It is a quantitative study. 21 students took part in the study. Data were interpreted based on t-test.	Achievement Test	SAS
X17	Sullivan, F.R.	2008	Article	It is a quantitative study. 26 people took part in the study. In the study, Scientific process skills and thinking skills were examined. Data obtained were submitted to t-test and interpreted accordingly.	Scientific Process Skills	SSPS
X18	Nugent, G., Barker, B., Grandgenett,N. & Adamchuck, V.I.	2014	Article	It is a quantitative study. 147 people took part in the study. Academic achievement test and attitude scale were used. The data collected were interpreted based on ANOVA, ANCOVA and t-test results.	Attitude and Success Scale	SAS SA
X19	Vollstedt, A.M., Robinson, M. & Wang, E.	2007	Notification	It is a quantitative study. 20 people took part in the study. Attitude scale and Physics test were used. The data were interpreted after they were submitted to Mann Whitney-U test and t-test.	Attitude and Achievement Scale	SPT SA
X20	Choi,S.H.	2013	Article	It is a qualitative study. 40 people participated in the study. Attitude and Interest scale were used. Data were interpreted based on t-test results.	Attitude and Interest Scale	SA SIM SPT
X21	Choi, Y. & Hong, S.H.	2013	Article	It is a quantitative study. 136 people took part in the study. 69 of these students made up the experimental group and 67 of them made up the control group. Their scientific process skills and academic success were examined.	Achievement test	SAS SSPS
X22	Kong, J., Ju, E., J. &Jang, S.	2013	Article	It is a quantitative study and 48 people took part in the study. 24 of them made up the experimental group while the rest made up the control group. The data collected were interpreted with t-test and f frequency statistics.	Achievement test and motivation and Interest scale	SIM SA SPT
X23	Song, J. Shin, S. & Lee, W.	2010	Article	It is a quantitative study and 56 people took part in the study. While 28 made up the experimental group, 28 made up the control group. The date were interpreted based on t-test results.	Attitude Scale	SA SPT
X24	Kwon, S.B., Nam, D.S & Lee, T.W.	2012	Article	It is a quantitative study. 80 people took part in the study. While 40 of the m were in the experimental group, the other 40 were in the control group. Data were interpreted with t-test.	Creativity test or scale	SCT
X25	Lee, H. et al.,	2012	Article	It is a qualitative. 251 took part in the study. Data were interpreted based frequency and percentages.	Interview Form	STV SPT
X26	Hsu, M.C., Purzer, S. & Cardella, M.E.	2011	Article	It is a quantitative study. 192 people took part in the study. The data collected based on Mean, SD, Mann-Whitney test, Bonferroni test.	Survey	STV
X27	Owens, D. B.	2014	PhD Dissertation	It is a quantitative study. 12 people took part in the study.	Interviews, document analysis, and field notes	STV
X28	Sahin, A., Ayar, M.C. & Adıguzel, T.	2014	Article	It is a quantitative study. 146 people took part in the study. In this case study, data were collected through observations, field-notes, and interviews.	Observations, field-notes, and interviews.	SIM
X29	Kong, Y.T. & Huo, S.C.	2014	Article	It is a quantitative study. 50 people took part in the study. While 25 of the were in the experimental group, the other 25 were in the control group. Data were interpreted with t-test.	Questionnaire of scientific attitude	SA

X30	Thomas, A.T.	2014	PhD Dissertation	It is a mixed study. 181 people took part in the study. Data were interpreted with ANOVA, Mann-Whitney U, t-test, post hoc test.	Receptivity to Integrated STEM Education in the Elementary Grades Survey Interview Questions	STV
X31	Wang, H.H., Moore, T.J., Roehring, G.H. & Park, M.S.	2011	Article	It is a qualititative study. 3 teachers took part in the study. Data were interpreted with comparative method.	Classroom Observation, A semi structured Interview perception, Document analysis of STEM Integration	STV
X32	Yıldırım, B., & Altun, Y.	2015	Article	It is a quantitative study. 83 people took part in the study. Data were interpreted with t-test.	Learning level test	SAS
X33	Gülhan, F. & Şahin, F.	2016	Article	It is a quantitative study. 55 people took part in the study. Data were interpreted with t-test.	STEM Perception Test, STEM Attitude Scale	SA
X34	Yıldırım, B.	2016	PhD Dissertation	It is a mixed study. 78 people took part in the study. The data were interpreted based on ANCOVA and t-test results.	STEM Attitude Scale, Achievement test, Motivation Scale, Interview Questions	SA, SAS, SIM, STV

Table 3. Distribution of Methodologies employed in STEM Education Studies

The Method used in the Study	f	%
Quantitative	24	70,58
Qualitative	7	20,58
Mixed	3	8,82
Total	34	100

The findings regarding the method distribution about the published articles, reports and theses on STEM education were given in the table above. When the findings were investigated, it was determined that quantitative studies were published more (24) while qualitative studies (%70,58) had an important percentage in total percentage. Also, it was determined that 20,58 % of the studies were conducted by using the qualitative method while 8,82 % of them were conducted by using the hybrid method.



Information about the type of studies that were conducted on STEM education was given in the table and figure above. 24 of these studies were articles, while 6 of them were theses and 4 of them were Research Paper and Notifications.

2.4 Data Analysis

Analysis of data is being investigated under 7 topics in meta synthesis (Nobit and Hare, 1998: Cited by: Cite: Aküzüm & Özmen, 2013):

First stage: Deciding on what the study will be conducted and beginning the study: this stage forms the first step of the study area that will be synthesized. The area selected for this study is "STEM/STEM Education".

Second stage: This is the stage at which the studies to be used in relation to the selected area will be decided. A literature scan is made for the studies needed for this study. The studies to be used in this study will be selected during the literature scan. Articles, reports and theses were specified according to the criteria that were determined in this study.

Third stage: This stage is about reading the data that is collected.

Fourth stage: This stage is about determining that data is interrelated. At this stage, it is aimed to reveal the difference and similarities between the studies by listing and comparing keywords, expressions, ideas and concepts. General features of the studies to be used in this study are specified in (Table 2). In addition to that, information obtained from reports, articles and theses are protected as much as possible and tables were formed for expressions and concepts (See Table 4).
Fifth stage: This stage is about the conversion of data.
Sixth stage: This is the stage during which a high-level abstraction was made as a result of including the data obtained in the studies.
Seventh stage: This stage is about making a synthesis by starting from the data that was obtained. Data was synthesized by using the above-mentioned stages in this study.

2.5 Validity Measures of The Study

Three validity types should be taken into consideration to ensure validity in meta synthesis works. These are (Sandelowski and Barroso, 2007):

Descriptive validity: This is the type of validity that includes describing the data that was obtained based on facts. Data was obtained by adhering to the articles, reports and theses in question in this study. For this reason, it can be said that this study has descriptive validity.

- Interpretive validity: This validity is about researchers representing their interpretations completely and accurately.
- Institutional validity: This type of validity applies the reliability of interpreting the findings. This means adhering to the method used for interpreting the data while combining the information (Aküzüm and Özmen, 2013).

3. Findings

In addition to general expressions given regarding the studies made on STEM education (see Table 2), provided that the expressions in the study dimensions regarding STEM education are protected by adhering to the steps of the meta synthesis study method, similar expressions were grouped and specified in Table 4. Thus, general findings of the study (see Table 2) were supported by qualitative and quantitative data. A large amount of findings regarding the themes were obtained by starting from these contributions.

Table 4. Key Expressions and Concepts with Regard to Themes

Themes	Expressions and Concepts with Regard to Themes	f	%
The effect of STEM education Academic Success or on Increase in Academic Knowledge	It does not have a significant effect on students' academic success or on the improvement of their academic knowledge.	4	11,76
	It has a positive effect on students' academic success or on the improvement of their academic knowledge	4	11,76
The effect of STEM education on Interest and Motivation	It does not have a significant effect on the increase in students' interest and motivation.	2	5,88
	It has a positive effect on the increase in students' interest and motivation.	9	26,47
The effect of STEM Education on Problem Solving Skills	It does not have a significant effect on the development of problem solving skills of students.	1	2,94
	It has a positive effect on the development of problem solving skills of students.	1	2,94
The effect of STEM Education on Creative Thinking Skills	It does not have a significant effect on the development of the students' creative thinking	-	0
	It has a positive effect on the development of the students' creative thinking.	3	8,82
The effect of STEM Education on Attitude	It does not have a significant effect on the development of students' attitude.	2	5,88
	It has a positive effect on the development of students' attitude.	8	23,52
The effect of STEM Eduction on Scientific Process Skills	It does not have a significant effect on the development of scientific process	2	5,88
	It has a positive effect on the development of scientific process.	1	2,94
The relation between STEM and PISA and TIMSS exams	The way to success on international exams like PISA and TIMSS passes through education in the fields of STEM.	8	23,52

When Table 4 in which the results of studies on STEM education is examined, it is seen that 34 studies reached indicate:

1. In 23,52% of the studies the effects of STEM education on students' academic success or academic knowledge were examined. In 11,76% of the studies, it was found out that that STEM education increased students' academic success and 11,76% of the studies found that it did not have positive

effect.

2. In 35,29%, the effect of STEM education on students' interest and motivation was examined. 8,82% of them found that STEM education was not influential in increasing students' interest and motivation, and 26,47% found that it had positive effect.
3. In 8,82% of the studies, the effect of STEM on students' critical thinking skills was examined. In 4,41% of these studies, it was revealed that STEM education did not have positive effect on students' critical thinking skills and had positive effect in 4,41%.
4. In 5,88% of these studies examined the effect of STEM education in problem solving skills. In 2,94% of the studies, it was found that STEM education did not have effect on problem solving skills of students and 2,94% found that it had positive effect.
5. In 29,41% of the studies examined the effects of STEM education on students' attitudes towards the lesson, STEM fields or towards STEM. In 5,88% of the studies, it was found that STEM education did not have effect on students' attitudes and 23,53% of them have positive effect on their attitudes.
6. In 8,82% of the studies, the effect of STEM education on students' scientific process skills. In 5,88% of these studies, it was found that STEM education did not have students scientific process skills and in 2,94% it was found that it has positive effect.
7. In %23,52 of the studies, it was revealed that there was a relation between PISA and TIMSS exam scores.

Table 5. Key Expressions and Concepts with Regard to Teacher views

Themes	Expressions and Concepts with regard to Teacher Views	F	%
Teacher views regard to STEM Education	STEM education is necessary	10	29,41
	STEM education can be particularly effective in primary schools		
	STEM education is an alternative teaching and learning method		
	There is not enough time to do activities related to STEM		
	It has a positive effect on students (Interest, Motivation, Attitude etc.)		
	A program and materials are to be available to teachers for STEM education		
	STEM enables students to understand science and use the science concepts they have learnt in new fields.		
	Engineering design process is necessary and important for students		
	It helps students to solve problems		
	As there is not enough accumulation of information about integrated STEM education, it is used very rarely in the classes		
	Even if there is not enough accumulation of information about integrated STEM education, it can be compensated via in-service training		
	Integrated STEM education is a problem-solving approach		
	Integrated STEM Education is an interdisciplinary approach		

When Table 5 in which the results of studies on STEM education is examined, it is seen that 34 studies reached indicate:

1. In 26,47% of the studies, teachers views of STEM education were examined. As a result of examination of the studies, it was determined that teachers are not adequately knowledgeable about STEM education; however, they have positive views about STEM education.

In this context, it was determined that STEM education increased students' academic success, enhanced students' attitude, interest and motivation, and contributed to their critical thinking and problem solving skills. Besides, it was found that STEM education contributed to scientific process skills. In the other two studies, it was found that it did not have positive effect. In addition, it was determined that teachers do not have adequate knowledge and skills related to STEM education. Beside this, it was determined in interviews that STEM education was beneficial.

4. Discussion

When the results of 34 studies made on STEM education were examined, the following points were determined as outstanding points. Similar results were obtained in studies carried out on similar subjects (Becker & Park, 2011).

When the expressions regarding the effect of STEM Education on academic success or the academic knowledge were examined, it was determined that students, who received STEM education, learned better and had better academic success compared to the one who did not received such education (Yıldırım & Altun, 2015). When the statements regarding the effect of STEM Education on problem solving and critical thinking skills were examined, it was determined it had a significant effect on the problem solving skills of students (Cotabish, Dailey,

Robinson & Hunghes, 2013; Kwon, Nam & Lee, 2012; Kim, Ko, Han, & Hong, 2014; Kim & Choi, 2012; Abdullah, Halim & Zakaria, 2014; Park, Nam, Moore & Roehring, 2011). However, there were only a few number of studies that could support the these results (Choi and Hong, 2013; Park and Yoo, 2013).

It was determined to have positive effect on students' improvement of their creative thinking skills and attitudes. When statements regarding the effect of STEM Education on attitude, interest and motivation were examined, it was determined that it improved the attitude, interest and motivation of students (Riskowski, Todd, Wee, Dark & Harbor, 2009; Sahin, Ayar &Adıguzel, 2014; Kong & Huo, 2014). When statements regarding the effect of STEM Education on scientific process skills were examined, it was determined that STEM had a significant effect on the development of scientific process skills. In spite of this, it was concluded during the pre-test and post-test that there was a significant development as a result of the application.

When teachers' opinions regarding STEM Education were examined, it was detemriend that teachers did not have sufficient knowledge and experience regarding STEM education and they could not use STEM disciplines together as a result of this. Teachers agreed that in-service training to be provided about STEM education would be useful (Thomas, 2014; Egli, 2012; Wang, 2012; Lee, Park & Jim, 2013). On the other hand, it was determined that there were positive opinions suggesting STEM would be effective for the improvement of students and it should be used during the courses. In addition, Integrated STEM Education is an interdisciplinary approach (Wang, Moore, Roehring & Park, 2011; Jacobs, 1989; Lederman & Niess, 1997).

5. Conclusion and Suggestions

This meta synthesis study was conducted as a guiding study for the studies to be made on STEM education in the future. Accordingly, qualitative, quantitative and hybrid methods were used and the studies that were conducted were examined. The following suggestions were given by starting from the data obtained as a result of the examination.

It will be useful to utilize STEM education including different disciplines in different subjects and lectures. One of the most important roles of STEM education is that it ensures teachers to be researching, questioning and criticized individuals. Teachers can develop themselves in these areas thanks to this. They can set goals according to this. Teachers working on STEM education will contribute the development of their researcher identities. Besides, sending teachers abroad for STEM education by using their own means and government support may contribute their development in this area.

Improvement and development might be ensured in this area by giving in-service education to teachers. However, rather than theoretical knowledge, the in-service education to be given must include applications based on problem-solving which are about project preparation and how STEM education will be used during lectures. Teachers' effectiveness in terms of STEM education depends on the sufficiency of their content knowledge, occupational knowledge and pedagogical knowledge. For this reason, multi-directional education programs should be prepared and these programs should be checked by receiving feedback.

Developments in STEM education and the technological developments occur in parallel with each other. Effective results are obtained in determining problems and achieving solutions thanks to these technological developments. For this reason, teachers should be encouraged to have interactions that will facilitate sharing of information about STEM education and their self-improvement in terms of STEM education.

To sum up, for teachers to be knowledgeable and skillful about STEM education, STEM pedagogical content knowledge (STEM PCK) for teachers is to be constructed. With the help of STEM PCK, teachers can be given adequate knowledge and competencies about STEM education. Therefore, STEM PCK constructed for teachers can be given to teachers and prospective teachers in pre-service and in-service teacher education.

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