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Research Paper

The Effects of STEM and Other Innovative Interdisciplinary Practices on Academic Success, Attitude, Career Awareness: A Meta-Synthesis Study

Agâh Tuğrul Korucu*[a], Kadir Kabak[b]

[a](ORCID ID: 0000-0002-8334-1526), Necmettin Erbakan University,Turkey,akorucu@erbakan.edu.tr
[b](ORCID ID:0000-0002-7747-2909), Necmettin Erbakan University, Turkey, kkabak10@gmail.com
*Corresponding author

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ABSTRACT
Today, the number of researches about STEM education, which is brought to the forefront by innovative interdisciplinary approaches, has been increasing over the years and each research is carried out in different areas, regions for different purposes. When these studies are examined, it is thought that the studies can be gathered under certain headings and themes and a broad perspective about the studies can be presented. We reached 186 works in the framework of STEM and other innovative approaches worldwide, except for Turkey. 48 of these studies from 21 different countries, written in 4 different languages, were selected between 2009-2019. These studies were evaluated in 9 different themes and 24 sub-concepts. These studies include all partners (students, teachers, parents and others) of the education system. The impact of innovative interdisciplinary practices on students' academic achievement, scientific process skills and career awareness is positive. Gender is an important factor in perception and attitudes. In-school and out-of-school activities are effective in acquiring 21st century skills. Education partner's attitude towards innovative interdisciplinary approaches is positive. In some studies, limitations such as physical space, time and cost disrupted the realization of activities and sometimes it was a negative situation that the teachers did not have the necessary training formation and felt inadequate for these activities. Existing curricula, which are shaped within the framework of knowledge-based examination system, were also seen as another limiting factor. At the end of the research, suggestions were made to all partners of the education system for the research and applications to be carried out in innovative interdisciplinary fields.

INTRODUCTION

New educational paradigms within the scope of 21st century skills explore content-rich possibilities that can increase students' interest in science and creative convergence (Kong & Huo, 2014).In innovative insights developed for this purpose, the approaches in which the teacher guides learning and the student is more active in the learning process are seen as viable (Demirel, 2010).In constructivist teaching method curriculum, the learner is supposed to have high-level thinking skills such as comprehension, use, editing, criticizing, interpreting and problem solving rather than receiving information as a simple message (Yurdakul, 2005).With STEM education, taking students core in active activities in the classroom has focused on. It emphasizes that it serves in order to prepare the 20th century workforce for the future and that educators and the business world should act in cooperation with each other (Ejiwale, 2013).

In a report by Timms, Moyle, Weldon and Pru (2018) on the Australian primary and secondary school education system, two arguments have been put forward as to why STEM education is important. First, STEM education is nominally a social obligation. STEM literacy is of great importance for addressing and solving real-world challenges. The second is an economic-based approach. In order to be able to withstand and secure global competition in the future, young people need to be equipped to meet national productivity demands. It is a necessity to take steps in line with all these needs. Otherwise, the best graduates may be lost through brain drain. The National Education Council took important steps in that direction in 2015.

Land (2013) conducted a survey in the United States (United States) that historically, The US leadership in innovation has recently led to a dramatic decline in innovation due to the inadequacy of innovative American ideas specified. In this context, the importance of art integration in STEM education is mentioned and the inadequacy of universities in the direction of creativity and innovation is emphasized. At this point, it is stated that there is a need for an art integration that will increase curiosity and self-motivation on the students.

In a study conducted by Affleck (2018) on private schools in Dubai, the capital of the United Arab Emirates, it was stated that countries around the world are focusing on STEM applications to develop innovative insights in the fields of science and technology. The level of meeting the needs of STEM education in terms of achieving high academic achievements in the international field has been questioned. Although the subjects such as science, technology, engineering and mathematics are very important for the economy, it has been emphasized in a way that other subjects are being developed and thus the applications of the STEAM model are being developed. These integrations will continue within the framework of innovation in

education. In a study conducted by Kong and Huo (2014) at the elementary school level, it was observed that most of the teachers had positive views on the STEAM education model, but their experience of performing such activities was low. The reason for this situation is that teachers did not receive training in the in-service and pre-service teacher training processes within the framework of STEAM training activities.

While the studies on updating the national education programs and contents of the world countries to meet the needs both regionally and internationally continue, different studies and practices are being observed in many countries in order to ensure that the outcomes of the education systems with the participation of all stakeholders are able to meet the needs of the future world. It is seen that some of these studies have gathered the studies carried out in certain frameworks at the regional and international level under a single title with the meta-analysis study.

Purpose of the Research

In our study, stem training practices obtained from local and international thesis and dissertation databases in various countries of the world and studies covering various stakeholders are examined. It was aimed to convey the methods and processes in which STEM applications are carried out, similarities, differences and conclusions of the applications in terms of the theoretical and application aspects between them. Our study seeks answers to the following questions:

(1) What are the different practices around STEM and other interdisciplinary innovative trainings around the world?
(2) Do STEM and other innovative interdisciplinary practices have a significant impact on academic achievement, attitude, perception, career skills and cognitive process skills?
(3) What are the spatial application areas of STEM and other innovative interdisciplinary education activities?
(4) What are the views of key stakeholders of education, such as parents, teachers, administrators, training specialists for STEM and other innovative interdisciplinary training?

Limitations

Studying the academic studies carried out in line with STEM in all countries of the world and collecting the application stages and results of the different activities in this framework in a compilation can provide a positive contribution to the new studies to be carried out in this direction both theoretically and in practice. The limitations of the research process are:

• In the last 10 years (2009-2019), researches in certain countries of the world were included in our study.
• In our study, the data to be obtained from the studies to be included in the meta-synthesis study is limited to the variables in the "meta-synthesis data generation tool".
• The sample of our study is limited to those that can be accessed from published sources from theses, articles and reports.
• Meta-synthesis is limited to the general limitations of the survey method.
• The study doesn't contain the works from Turkey origin.

METHOD

In recent years, as a result of the increasing importance of qualitative academic studies in social sciences and the number of studies carried out, meta-synthesis method has emerged with the need to gather studies in similar fields under a common roof. Thanks to this method, the possibility of an in-depth examination of studies on a subject can be created in various ways (Polat & Ay, 2016). Meta-synthesis studies can be used in theory development studies in order to reach generalizable results by examining and synthesizing all research results (Hunter & Schmidt, 2004).

In our study, meta-synthesis method, which is a qualitative research design, was used to synthesize different researches obtained from various sources for the same purpose. To carry out a meta-synthesis study first of all the studies should be found in accordance with the problem and researchers should refer to statistical foundings which is necessary for meta synthesis also it should be appropriate in terms of reporting rules (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2017). When the previous meta-synthesis studies were examined, it was seen that the process steps used in carrying out the study were similar. (Polat & Ay, 2016). When the studies are examined in general, it is stated that these process steps are listed as shown in Table 1. These steps were followed in our study.

Table 1. Process Steps of Meta-Synthesis Research

Steps	Explanation
1	Identifying the research problem.
2	Determining the appropriate keywords in the subject of the work done literature review.
3	Provision, review, identification and evaluation of resources.
4	Determination of the inclusion of exclusion criteria and selection of research and study will be evaluated.
5	Analyzing selected works and creating common themes and sub-themes of these themes, revealing similar and different aspects.
6	Synthesis of the findings obtained within the themes and

	making inferences.
7	Detailed reporting of the process and findings.

Data Collection

National and international databases were used to reach the researches that will contribute to the study. In this process, the national databases of some countries (Japan, South Korea, Finland, Netherlands, Pakistan, Taiwan, etc.) were accessed from a web page (Networked Digital Library of Theses and Dissertations (NDLTD)).
In the national databases reached, keywords were used in local languages within the framework of STEM education and it was tried to reach the researches published between2009-2019. Parallel studies with this method, Google Scholar, Educational Resources Information Center (ERIC), Springer Link, Research Gate YÖK National Thesis Center and University of national databases of various countries were sought.

186 studies were collected including one or more terms STEM, STEAM, STEM Education, STEAM Education, Transdisciplinary Instruction, Interdisciplinary Learning, Innovative Application, STEM Experimental. 48 studies were included in the study according to the following criteria:

- Studying the effects of STEM education on various variables (perception, attitude, academic achievement, career, scientific process skills, etc.).
- Clear specification of data collection method used in the operation of the research design.
- Specifying the sample group to be of considerable size.
- The keywords of the studies should include STEM, STEAM or any of the interdisciplinary concepts.
- Specifying the research design.
- Specify the data collection tool used

Coding Method

The themes of academic research covered by the study, all of the quantitative and qualitative findings were coded as shown in Table 2.

Table 2. Meta-Synthesis Coding Method

Themes	**Theme Coding**
Current Curriculum Opinions	CCO
Classroom Activities	CA
Out of School Applications	OSA
Academic Success	AS
Perceptions of Education	POE
Attitudes Towards Education	ATE
Scientific Process Skills	SPS
Career Awareness	CRA
Opinions on Education	OE

Researches Included in Meta- Synthesis

Information on the year, type of publication, author, research model, sample group and research theme of the studies included in the study are presented in Table 3.

When Table 3 is examined, it is seen that 5 of them are papers (10.4%), 28 of them are articles (58.3%), 6 of them are master's thesis (12.5%) and 9 of them are doctoral thesis (18.8%).The distribution of the studies by years is shown in Table 3.

Table 3. Distribution of Employees in the Research by Years

Year	Frequency	Percent
2009	1	2,1
2011	1	2,1
2012	3	6,3
2013	1	2,1
2014	6	12,5
2015	4	8,3
2016	7	14,6
2017	13	27,1
2018	10	20,8
2019	2	4,2

Our study was carried out as followed by the process steps of meta-synthesis as specified in Table 1 and as followed as follows.

Step 1: Identifying the research problem
STEM, STEAM and other innovative interdisciplinary training activities have been identified as working areas. In this context, the effects of these activities on situations such as academic achievement, attitude, perception and cognitive process skills were examined. In addition, it was aimed to investigate the effects of the practices on students' career awareness and the opinions of other important education stakeholders such as teachers, parents, experts and administrators in this field.

Step 2: Identify the appropriate keywords and search for the literature
While searching the literature within the scope of the study, words such as STEM, STEAM, interdisciplinary and transdisciplinary were used, and within the framework of these keywords, various words were searched in the archives of countries, universities and international thesis databases in national languages and English. As a result of these searches, 186 papers, articles, master and doctoral theses were reached in this context.

Step 3: Provision, review, identification and evaluation of resources
The 186 studies reached were grouped in terms of various variables such as country, year, research method and research topic, and the themes and explanatory concepts of the themes were identified by using meta-synthesis identification tool and the studies were analyzed in order to ensure the interconnection of the studies in different fields.

Step 4: Determining the inclusion and exclusion criteria of the research and selecting the studies to be evaluated
48 studies were included in the study considering the representations of the studies obtained in the literature, the studies in various regions of the world, the number of participants, research methods, data collection tools used, the suitability of the meta-synthesis to the keywords, the clarity and clarity of the expressions in the results stage.

Step 5: Resolving selected conflicts, creating common themes and sub-themes of these themes, revealing similar and different aspects.
48 studies in selected different languages (43 English, 3 Japanese, 1 Korean, 1 Portuguese) are ready to be transferred to tagged tables in terms of information such as author, year, publication type, data collection tools, sample group, and sample selection method was introduced.

Step 6: Synthesizing the findings of the themes and making inferences
It was determined which themes (views on current curriculum, academic achievement, scientific process skills, views on education, perceptions on education, etc.) were chosen in terms of STEM and other innovative interdisciplinary trainings. It is grouped.

Step 7: Detailed reporting of the process and findings.

The data were grouped according to various variables.

Table 4. Studies and Codes Included in Meta-Synthesis

Working Code	Year	Post Type	Author	Research Model Sample Group	Theme[1]
C_1	2019	Article	Lin, Wang, & Wu	[a]Mixed Method Research [b]149 Student(High School)	CA, AS, SPS
C_2	2019	DoctoralThesis	Flick	[a]Mixed Method Research [b]206 Student (Mid-School), 32 Parents, 8 Teacher	AS, OE
C_3	2018	Article	Taylor, McLean, Duncan, Jayasuriya, Dodd, & Whiting	[a]Qualitative method research [b]115 Student(High School)	OSA
C_4	2018	Master Thesis	Mutakinati	[a]Mixed Method Research [b]271 Student (Mid-School)	CCO, SPS, POE, ATE
C_5	2018	Article	Blotnicky, Odendaal, French, & Joy	[a]Mixed Method Research [b]1448 Student (Mid-School)	OSA, CA, SPS, CRA

C_6	2018	Article	Vossen, Henze, Rippe, Van Driel, & De Vries	[a]Quantitative method research [b]1625 Student (Mid-School and High School)	SPS, POE
C_7	2018	Article	Shin, Rachmatullah, Roshayanti, Ha, & Lee	[a]Quantitative method research [b]2171 Student (Mid-School and High School)	CA, CRA, ATE
C_8	2018	Article	Tran	[a]Mixed Method Research [b]183 Student (Mid-School)	ATE, POE, CRA
C_9	2018	Article	Rusman, Ternier, & Specht	[a]Mixed Method Research [b]26 Student(Primary School)	AS, CA
C_{10}	2018	Article	Koul, Fraser, & Nastitia	[a]Mixed Method Research [b]1095 Student (Pre-School)	POE OE CRA
C_{11}	2018	Doctoral Thesis	Jones	[a]Quantitative method research [b]173 Student(High School)	ATE, CRA
C_{12}	2018	Article	Kang, Barton, Tan, Simpkins, Rhee, & Turner	[a]Qualitative method research [b]1821 Student (Mid-School)	ATE, POE
C_{13}	2017	Doctoral Thesis	Gibson	[a]Mixed Method Research [b]111 (High School Student, Teacher and Parents)	POE, ATE, OE
C_{14}	2017	Article	Tippett & Milford	[a]Mixed Method Research [b]103 (Pre-School student and teacher)	ATE, OSA
C_{15}	2017	Doctoral Thesis	CJ Pozarski	[a]Quantitative method research [b]4123 (Middle School, High School Students and teachers)	ATE, AS
C_{16}	2017	Article	Hsu, Lin, & Yang	[a]Quantitative method research [b]32 Student (High-School)	CRA, OE
C_{17}	2017	Article	Cohen, Renken, & Calandra	[a]Quantitative method research [b]183 Student (Mid-School) and 12 Professional Educater	OSA, OE
C_{18}	2017	Article	Gumaelius & Nymark	[a]Quantitative method research [b]3439 Student (Mid-School)	OSA, ATE
C_{19}	2017	Article	Achilleos vd.	[a]Quantitative method research [b]152 Student (Mid-School and High School)	POE ATE
C_{20}	2017	Master Thesis	Heck	[a]Qualitative method research [b]138 Student (High-School)	OE, AS, SPS,
C_{21}	2017	Article	Vennix, den Brok, & Taconis	[a]Quantitative method research [b]729 Student (High-School) and 13 Teacher	OSA, ATE
C_{22}	2017	Article	Luneeva & Zakirova	[a]Qualitative method research [b]200+ Student (High-School) and 229 Teacher	SPS
C_{23}	2017	Article	Mayorova, Grishko, & Leonov	[a]Quantitative method research [b]2403 Student (High-School) and 138 Teacher	CRA, OE
C_{24}	2017	Article	Sáinz & Müller	[a]Quantitative method research [b]796 Student (High-School)	ATE, POE, CRA
C_{25}	2017	Article	Mäkelä, Pnevmatikos, Immonen, Fachantidis,	[a]Qualitative method research [b]6 Student (Primary School), 8 Student (Mid-School) and 4 Student (High-School) 9	OE, OSA, CRA

			Kankaanranta, &Christodoulou	teacher, 6 manager, 11 parent, 7 stem specialist	
C_{26}	2016	Article	King & English	[a]Qualitative method research [b]24 Student (Mid-School)	CA, OE
C_{27}	2016	Article	Tamayama vd.	[a]Mixed Method Research [b]27 Student (License)	ATE, AS
C_{28}	2016	Report	Tomoki Saito	[a]Qualitative method research [b]13(Primary School, License and Half Expert)	SPS, OE
C_{29}	2016	Master Thesis	Cole	[a]Quantitative method research [b] 285 Student (License)	SPS, POE, AS
C_{30}	2016	Article	Lin & Williams	[a]Quantitative method research [b]139 Teacher	CCO, OE
C_{31}	2016	Article	Park, Byun, Sim, Han, & Baek	[a]Quantitative method research [b]705 Teacher	OE, CCO
C_{32}	2016	Article	Chonkaewa, Sukhummek, & Faikhamta	[a]Mixed Method Research [b]90 Student (High School)	SPS, AS, CA
C_{33}	2015	Doctoral Thesis	Armknecht	[a]Mixed Method Research [b]30 Student, 75 Parents and 17 Teacher	ATE, OE, AS
C_{34}	2015	Article	Kim & Cho	[a]Quantitative method research [b]37 Student (Primary School)	SPS, ATE
C_{35}	2015	Report	El-Deghaidy & Mansour	[a]Qualitative method research [b]23 Teacher	OE, ATE
C_{36}	2015	Article	Jeong & Kim	[a]Quantitative method research [b]145 Student (Mid-School)	ATE, POE, AS
C_{37}	2014	Master Thesis	Suwarma	[a]Mixed Method Research [b]784 Student(Primary, Middle and License)	OSA, SPS, OE
C_{38}	2014	Article	Kong & Huo	[a]Mixed Method Research [b]50 Student (Primary-School)	ATE, POE
C_{39}	2014	Report	Nomura & Ito	[a]Mixed Method Research [b]31 Student (Primary-School)	ATE SPS
C_{40}	2014	Article	Meng, Idris, & Eu	[a]Quantitative method research [b]1005 Student (Mid-School)	POE CA
C_{41}	2014	Doctoral Thesis	Rabalais	[a]Quantitative method research [b]36000+ Student (High-School)	AS, POE, ATE
C_{42}	2014	Master Thesis	El Sayary	[a]Mixed Method Research [b]1800 Student (High-School) and 112 Teacher	CA, SPS, OE
C_{43}	2013	Article	Knezek, Christensen, Wood, & Periathiruvadi	[a]Quantitative method research [b]246 Student (Mid-School)	SPS, ATE, POE, OE, CA, AS
C_{44}	2012	Doctoral Thesis	Olivarez	[a]Mixed Method Research [b]176 Student (Mid-School)	AS, SPS
C_{45}	2012	Master Thesis	Egli	[a]Qualitative method research [b]16 Teacher	CA, OE, SPS

C_{46}	2012	Article	Oh, Lee, Kim, & Kim	[a]Quantitative method research [b]24 Student (Mid-School)	SPS, ATE
C_{47}	2011	Doctoral Thesis	Mustafa	[a]Mixed Method Research [b]60 Student (High-School) and 681 teacher	CA, AS, OE, CCO
C_{48}	2009	Doctoral Thesis	Peng	[a]Quantitative method research [b]255 Student (Mid-School)	SPS, CA, ATE

[1]The explanations of the codes are shown in Table 2.

RESULTS

Meta-synthesis was conducted in 4 different languages (43 English, 3 Japanese, 1 Korean, 1 Portuguese) from 21 countries around the world. The distribution of the studies by countries is as shown in Table 5.

Table 5. Distribution of Countries Applied to the Research

Country	Frequency	Percent
United States of America	14	29,2
European	1	2,1
Australia	2	4,2
United Arab Emirates	1	2,1
Brazil	1	2,1
Indonesia& South Korea	1	2,1
Indonesia& Japan	2	4,2
Finland&Greece	1	2,1
South Korea	5	10,4
Netherlands	3	6,3
Spain	1	2,1
Swedish	1	2,1
Japan	2	4,2
Canada	2	4,2
Malaysia	1	2,1
Pakistan	1	2,1
Russia	2	4,2
Saudi Arabia	1	2,1
Thailand	2	4,2
Taiwan	3	6,3
New Zealand	1	2,1

When Table 5 is examined, it is seen that the 14 most studies are selected from the United States, 21 studies from Asian countries, 7 studies are conducted in European countries and the other 6 studies are conducted in different continents. The research models of the studies are shown in Table 6.

Table 6. Distribution of Research Model

Research Model	Frequency	Percent
Quantitative Research	22	45,8
Qualitative Research	9	18,8
Mixed Method	17	35,4

When Table 6 is examined, it is seen that the studies to be included in the meta- synthesis study are quantitative and mixed model studies (81.2%) as the research model. The data collection tools used by the quantitative and qualitative models in the researches are shown in Table 7.

Table 7. Data Collection Tools Used in Research

Model	Data Collection Tool	Frequency	Percent
Qualitative Model	Drawing	1	0,8
	Open-Ended Questions	11	8,3
	Semi-Structured Interviews	9	6,8
	Interview Form	13	9,8
	Observation	12	9,1
	Audio Recordings	5	3,8
	Video Recordings	1	0,8
Quantitative Model	Scale	34	25,8
	Survey	23	17,4
	Academic Achievement Test	16	12,1
	Scientific Process Skill Test	6	4,5
	Transcript Information	1	0,8

When Table 7 is examined, it is seen that interview form, observation, open-ended questions and semi-structured interviews are used extensively in the researches that use qualitative model as research model. In the quantitative model research, questionnaire and scale were used extensively, while academic achievement tests were preferred in this process. Sample selection methods of the studies are shown in Table 8.

Table 8. Sample Selection Method

Sample Selection Method	Frequency	Percent
Random	4	8,3
Easily Accessible Sampling	32	66,7
Purposeful Sampling	12	25

When Table 8 is analyzed, it is seen that most of the studies (66.7%) prefer easy-access sampling in sample selection. The reason for this is the limitation of time variation in studies conducted on students. The values showing the sample groups in the studies within the scope of the research are given in Table 9.

Table 9. Sample Groups in the Studies

Sample Groups	Frequency	Percent
Pre-School	2	2,6
Primary School	8	10,4
Middle-School	21	27,3
High School	19	24,7
License	4	5,2
Teachers	16	20,8
Parents	5	6,5
Experts	1	1,3
School Administrators	1	1,3

When the study groups in Table 9 were examined, 21 students (27.3%) were the most preferred secondary school students. This group was followed by high school (24.7%) with 19 studies and teachers with 16 studies (20.8%), respectively. In some studies, there were more than one sample preferences such as the selection of teachers and students as sample groups or the selection of high school and secondary school students as student levels.

As a result of step 5 of Table 1, "Analysis of selected studies, creating common themes and sub-themes related to these themes, revealing similar and different aspects", all selected articles were examined and common themes and sub-concepts related to these themes were formed are shown as shown.

Table 10. Key Phrases and Concepts

Themes	Key Phrases and Concepts	Frequency	Percent
Current Curriculum Opinions	The existing curriculum has a negative impact on the implementation of innovative methods.	2	0,80%
Out-of-School Applications	Out-of-school activities are effective	8	3,10%

	on learning.		
	Out-of-school activities influence 21st century skills.	4	1,60%
	The opinions of the students about classroom activities are positive.	19	7,40%
Classroom Activities	Classroom activities are effective on scientific creativity and problem-solving processes.	14	5,40%
	Applications have favorable impact on academic achievement.	19	7,40%
Academic Success	Applications do not have a significant impact on academic achievement.	1	0,40%
	Gender is effective on perceptions.	12	4,70%
Perceptions of Activities	School type is effective on perceptions.	1	0,40%
	Gender is effective on attitudes.	14	5,40%
	Parents' education level is effective on attitudes.	6	2,30%
Attitudes Towards Events	Activities have a positive effect on student attitudes.	32	12,40%
Scientific Process Skills	Activities have an impact on scientific process skills.	19	7,40%
	Activities have an impact on students' choice of profession.	11	4,30%
Career Awareness	Activities affect interest in STEM areas.	17	6,60%
	Activities have a positive impact on students' orientation to engineering areas.	4	1,60%
	Trainings include problem solving; motivation, interest etc. are effective on.	27	10,50%
	It is necessary for students to teach engineering processes.	6	2,30%
	The reason for the non-implementation of activities is time, cost and physical conditions.	12	4,70%
Opinions on Education	Teachers don't have sufficient prior knowledge of innovative activities.	8	3,10%
	Activities have an impact on pre-service teachers' perceptions of interdisciplinary education.	4	1,60%
	Activities are concentrated around the concept of science.	1	0,40%
	Teachers' attitudes towards STEM are generally positive.	14	5,40%
	Class level is an important factor in the practicing activities.	3	1,20%

As can be seen in Table 10, the common concepts of the studies were formed. When the findings of the data obtained from 48 studies were examined:

When the views of C4and C47 studies on the current curriculum are examined, it is seen that the existing curricula based on knowledge and memorization and the textbooks created within these curricula are not sufficient and supportive for STEM and other interdisciplinary applications. In 8 studies out-of-school practices carried out within the framework of interdisciplinary activities, studies have positive effects on students' learning, and in 4 studies, students have positive effects on 21st century skills such as problem solving, discussion and interpretation. It was stated that the students' views on innovative interdisciplinary activities were positive in 19 of 33 studies in which classroom activities were carried out. In 14 studies, it was stated that activities had positive effects on scientific creativity and problem solving processes.

As a result of the evaluations made in 19 of the studies, it was stated that the activities had positive effects on the academic achievement of the students. However, in the doctoral dissertation study conducted by Armknecht (2015) with 30 students, 75

parents and 17 teachers, no significant effect was observed on the academic achievement of the students. Gender has an impact on perceptions of STEM and other innovative interdisciplinary activities. In addition, in one study (C40), it was observed that the school type factor was important.

When the data collected about students 'attitudes towards the activities were examined, it was observed in 32 studies that students' attitudes towards STEM and other innovative interdisciplinary approaches were positive. In 14 studies, it was observed that gender factor was effective on students' attitudes, and in 6 studies, it was observed that the education level of parents was an important factor. Positive evaluations were made in 19 studies that examined the effects of the studies on scientific process skills.

In 11 of 32 studies examining the effects of STEM and other innovative interdisciplinary approaches on the course of career awareness, it was evaluated that the activities were effective in students' choice of profession. In 17 studies, it was observed that the activities affected the interest in STEM fields in terms of career awareness and in 4 studies it increased the interest in engineering fields.

In the studies, opinions of the important stakeholders of education such as students, teachers, parents, experts and administrators about education were also examined. When the findings obtained from the studies involving teachers and parents were examined, 27 of these studies showed that problem-solving, motivation, interest, etc. of the course environments created by STEM and other interdisciplinary methods. Variables were observed. 12 studies stated that such applications require certain cost, duration and physical conditions (technological infrastructure, workshop, etc.), but that one or more of these applications are not or cannot be realized due to lack of efficiency.

When the opinions on the trainers were examined, it was observed that the opinions of the trainers towards STEM and other innovative practices were positive in 14 studies. However, it was stated in 8 studies that pre-service teachers do not have the pedagogical knowledge and other preliminary information required to carry out these studies efficiently.

DISCUSSION AND CONCLUSION

In our study, a total of 48 studies examining STEM and other innovative interdisciplinary approaches in various countries of the world in the last 10 years (2009-2019) were combined into a meta-synthesis. Care was taken to include the studies in different countries of the world. All of the research studies are published in foreign languages occurred outside of Turkey.

When the findings obtained from the studies were examined, it was observed that the learning environments created using STEM and other innovative interdisciplinary methods had positive effects on the variables such as academic achievement, attitude, perception, motivation and scientific process skills. As a result of observing these values, it is observed that the opinions of other stakeholders (teachers, parents and experts, etc.) on the way of teaching the courses and creating such innovative learning environments are positive (Table 10).

At the beginning of the study, STEM, STEM Education, STEAM Education, Transdisciplinary Instruction, Interdisciplinary Learning, Innovative Application, STEM Experimental terms were used in the literature search in the field of STEM and 186 studies were reached from different countries. When these studies are examined, it is seen that countries tend to use STEM and other innovative interdisciplinary approaches in national education systems. In addition, when Table 4, which shows the distribution of such studies by years, can be observed numerically as we approach today.

As a result of the researches and necessities of STEM, which is the popular name of interdisciplinary practices, various integrations such as art and entrepreneurship fields are realized. In some countries, projects and practices using innovative interdisciplinary approaches are carried out under different labels. In Turkey, technological infrastructure improvement movements and various national projects support STEM applications. Examples of these are science fairs and the Project for Improving Opportunities and Technology Improvement (FATIH) Project conducted by TUBITAK.

In a report published by Ulutan (2018) within the Ministry of National Education, it is seen that innovative interdisciplinary practices in the world countries appear in different ways, sometimes on project-based and institutional basis. For example, Selective STEM Schools, which accept students according to certain criteria in the United States, include Inclusive STEM Schools and Inclusive STEM Schools, which are created to create and guide career awareness to students of all socioeconomic groups, and in particular minority groups, without academic achievement. STEM-Focused Career and Technical Education (STEM), which provides training similar to the vocational and technical education institutions in our country. Looking at European countries, not every country focuses on a common issue, while countries such as Germany, Norway and the Netherlands tend to increase women's interest in science, while some countries focus more on minorities. Figure 1 shows countries with general and local strategies in Europe.

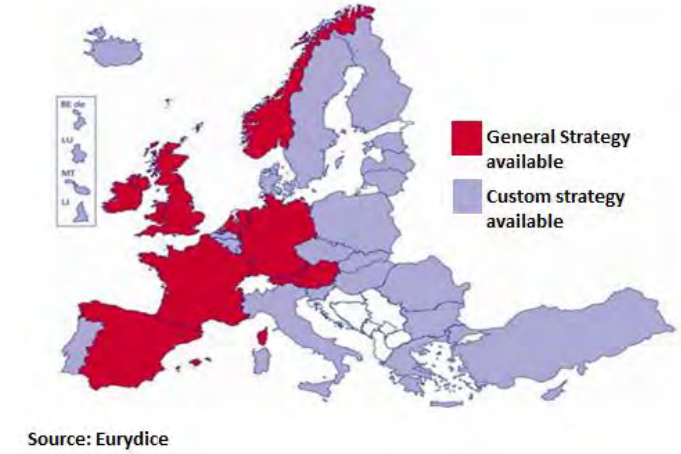

Figure 1. Countries with a General National Strategy for Science Education in Europe

The inadequacy of existing curriculum programs in countries has a negative impact on STEM practices. In the studies conducted by Mutakinati (2018) and Mustafa (2011), STEM and other innovative interdisciplinary activities were evaluated in terms of the book and information based examination system used as a sign of restrictive situation.

From the assessments on teachers, who are one of the important stakeholders of education, to their proficiency in processing courses using STEM and other innovative interdisciplinary methods, before service and service a significant number of teachers do not feel adequate about this.However, since teachers' attitudes towards STEM are observed to be positive, it is observed that teacher training is efficient in order to increase their proficiency in STEM and other innovative interdisciplinary training. it is necessary to be carried out in some way supported by national studies.

In some countries, it is seen that the STEM model is tried to be integrated into the national assessment exams. In a study conducted by Gumaelius and Nymark (2017) and included in our meta- synthesis study (C18), the Teknikattan exam, which is a science, mathematics and technology tournament involving 15-year-old students in Sweden, includes approximately 30% of the target group each year. The results obtained are examined on the basis of various values such as gender, academic achievement and whether the findings can be used to evaluate the knowledge of the youth in related subjects and whether such assessment can form a common understanding of the knowledge of the youth. This kind of exam activities that measure 21st century skills can be considered to provide a more valid and accurate career guidance for students according to their own skills.

SUGGESTIONS

When the 48 studies included in the meta- synthesis study are examined, it is seen that STEM practices differ in terms of the areas covered by the national and international way of application, the mass applied and the label used. In this case, in terms of all education stakeholders in each country to analyze their demographics, attitudes, expectations and opinions of assessment, perform research in terms of various factors and pilot applications in the pre-event STEM and other innovative interdisciplinary applications of great importance in order to avoid the problems which can be experienced later to implement all the consequences thereof it is.

STEM and other innovative interdisciplinary applications while performing grade level of students, readiness, regional differences, gender factors, such as factor in school types must be considered. Taking into account the effects of these factors, more efficient and inclusive activities can be realized as a result of the design of the activities specific to the region.

Necessary technological and educational infrastructure studies should be carried out considering the regional factors in terms of STEM activities. It is of great importance that innovative interdisciplinary activities are spread throughout the country and that every child is given important opportunities in order to achieve very useful outcomes.

While innovative interdisciplinary approaches are realized within the framework of labels such as STEM, STEAM and ESTEM today, the areas covered by it have increased over the years, as seen in our meta- synthesis contents, and a quantitative and qualitative development has been observed. In this case, when the conditions in our country, an innovative interdisciplinary approach to the curriculum and made according to the needs of renovation work to be carried out to cover all educational content.

The teacher is undoubtedly the most important factor in all of the innovative practices in the field. Our teachers should receive the necessary trainings efficiently both before and during the service. In order to implement and maintain innovative practices efficiently, all of these need to be adopted by teachers and provided with opportunities for implementation (time, cost, physical conditions, etc.). When the studies were examined, it was seen that exam anxiety in the current curricula negatively affected STEM practices (C47). In order to make the evaluations more valid and to reach the career opportunities of the students more accurately, the content of the national assessment exams are shaped while similar practices such as Teknikattan exam are carried out and the results can be integrated into the examination systems after analyzing and evaluating (C18).

In summary, many studies have shown that the interdisciplinary approach has achieved fruitful results in order to ensure the activeness of the student, regardless of which label. It is observed that training should be evaluated and specially prepared in

various aspects for all stakeholders in order to carry out these practices efficiently. When the current educational strategies and exam systems of the countries are established within the framework of this understanding, it can be seen that concerns such as inability to develop the existing curriculum during the time, duration and implementation phase may disappear over time. This can positively affect the attitudes and perceptions of all stakeholders towards activities. Thus, activities can be realized more efficiently and purposefully.

REFERENCES

Achilleos, A. P., Mettouris, C., Yeratziotis, A., Papadopoulos, G. A., Pllana, S., Huber, F., &Dinnyes, A. (2018). SciChallenge: a social media aware platform for contest-based STEM education and motivation of young students. *IEEE Transactions on Learning Technologies*, *12*(1), 98-111.

Affleck, F. (2018). Enabling Innovation throughMindset: Private Schools in Dubai, United Arab Emirates.

Armknecht, M. P. (2015). *Case study on the efficacy of an elementary STEAM laboratory school* (Doctoral dissertation, Lindenwood University).

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International journal of STEM education*, 5(1), 22.

Büyüköztürk, Ş., Çakmak, E. K., Akgün, Ö. E., Karadeniz, Ş., &Demirel, F. (2017). Bilimsel araştırma yöntemleri [Scientific Research Methods in Education]. *Pegem Atıf İndeksi*, 1-360.

Chonkaew, P., Sukhummek, B., & Faikhamta, C. (2016).Development of analytical thinking ability and attitudes towards science learning of grade-11 students through science technology engineering and mathematics (STEM education) in the study of stoichiometry. *Chemistry Education Research and Practice*, *17*(4), 842-861.

Cohen, J. D., Renken, M., & Calandra, B. (2017). Urban Middle School Students, Twenty-First Century Skills, and STEM-ICT Careers: Selected Findings from a Front-End Analysis. *TechTrends*, *61*(4), 380-385.

Cole, P. (2016). Measuring the Effectiveness of Software-Based Training to Improve the Spatial Visualization Skills of Students in STEM Disciplines in Higher Education Institutions.

Demirel, T. (2010). Bloglarin Öğretim Amaçli Kullanimi Üzerine Öğretmen Adaylarinin Görüşleri [Teachers' Opinions on the Use of Blogs for Teaching Purposes]. *Unpublished master's thesis, Atatürk Üniversitesi, Erzurum, Turkey.*

Egli, S. (2012).Using STEM education to promote 21st century math skills. *Unpublished master dissertation, Minot State University, North Dakota*.

Ejiwale, J. A. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning*, *7*(2), 63-74.

Sayary, E., & Adel, A. M. (2014). *The Effectiveness of Problem-Based Learning Strategy in STEM Education for Enhancing Students' 21st Century-Skills* (Doctoral dissertation, The British University in Dubai (BUiD)).

El-Deghaidy, H., & Mansour, N. (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching*, *1*(1), 51-54.

Flick, A. (2019). *The Effects of Flipped Learning in the Sixth-grade Mathematics Classroom* (Doctoral dissertation, Missouri Baptist University).

Gibson, J. J. (2017). *An Assessment of Factors Relating to High School Students' Science Self-Efficacy* (Doctoral dissertation, Pepperdine University).

Gumaelius, L., & Nymark, T. (2017). The Technology-Eight Competition: An analysis of Year 8 Students' Quiz Results. *NorDiNa: Nordic Studies in Science Education*.

Heck, C. (2017). Integração de tecnologia no ensino de fisicanaeducaçãobásica: um estudo de casoutilizando a experimentaçãoremotamóvel (Doctoral dissertation, Universidade Federal de Santa Catarina).

Hsu, Y. S., Lin, Y. H., & Yang, B. (2017). Impact of augmented reality lessons on students' STEM interest. *Research and Practice in Technology Enhanced Learning*, 12(1), 1-14.

Hunter, J. E., & Schmidt, F. L. (2004). *Methods of meta-analysis: Correcting error and bias in research findings*. Sage.

Jones, C. A. (2018). *Perceptions of Students on the Impact of Science, Technology, Engineering, and Mathematics Integration on High School Career Choices* (Doctoral dissertation, Tennessee State University).

Jeong, S., & Kim, H. (2015).The Effect of a Climate Change Monitoring Program on Students' Knowledge and Perceptions of STEAM Education in Korea. *EURASIA Journal of Mathematics, Science & Technology Education, 11*(6), 1321-1338.

Kang, H., Calabrese Barton, A., Tan, E., D Simpkins, S., Rhee, H. Y., & Turner, C. (2018). How do middle school girls of color develop STEM identities? Middle school girls' participation in science activities and identification with STEM careers. Science Education, 103(2), 418-439.

Kim, M. K., & Cho, M. K. (2015). Design and implementation of integrated instruction of mathematics and science in Korea. EURASIA *Journal of Mathematics, Science and Technology Education*, 11(1), 3-15.

King, D., & English, L. D. (2016). Engineering design in the primary school: Applying STEM concepts to build an optical instrument. *International Journal of Science Education*, *38*(18), 2762-2794.

Knezek, G., Christensen, R., Tyler-Wood, T., &Periathiruvadi, S. (2013).Impact of Environmental Power Monitoring Activities on Middle School Student Perceptions of STEM. *Science Education International*, *24*(1), 98-123.

Kong, Y. T., &Huo, S. C. (2014). An effect of STEAM activity programs on science learning interest. *Advanced Science and Technology Letters*, *59*, 41-45.

Koul, R., Fraser, B., & Nastiti, H. (2018). Transdisciplinary instruction: Implementing and evaluating a primary-school STEM teaching model. International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 26(8). 17-29.

Land, M. H. (2013). Full STEAM ahead: The benefits of integrating the arts intoSTEM. *Procedia Computer Science*, *20*, 547-552.

Lin, K. Y., & Williams, P. J. (2016). Taiwanese preservice teachers' science, technology, engineering, and mathematics teaching intention. *International Journal of Science and Mathematics Education*, *14*(6), 1021-1036.

Lin, Y. T., Wang, M. T., & Wu, C. C. (2019). Design and Implementation of Interdisciplinary STEM Instruction: Teaching Programming by Computational Physics. *The Asia-Pacific Education Researcher*, *28*(1), 77-91.

Luneeva, O. L., &Zakirova, V. G. (2017).Integration of Mathematical and Natural-Science Knowledge in School Students' Project-Based Activity. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(7), 2821-2840.

Mäkelä, T., Pnevmatikos, D., Immonen, H., Fachantidis, N., Kankaanranta, M., & Christodoulou, P. (2017). Considering Various Stakeholders' Views in the Design of a Hybrid Stem Learning Environment : Perceptions From Finland and Greece. In L. G. Chova, A. L. Martínez, & I. C. Torres (Eds.), EDULEARN17 Proceedings. 9th International Conference on Education and New Learning Technologies (pp. 5517- 5526). IATED Academy. doi:10.21125/edulearn.2017.2257

Mayorova, V., Grishko, D., &Leonov, V. (2018).New educational tools to encourage high-school students' activity in stem. *Advances in Space Research*, *61*(1), 457-465.

Meng, C. C., Idris, N., & Eu, L. K. (2014). Secondary students' perceptions of assessments in science, technology, engineering, and mathematics (STEM). Eurasia *Journal of Mathematics, Science and Technology Education*, 10(3), 219-227.

MUSTAFA, J. (2011). *Development of integrated activity based mathematics curriculum at secondary level in North West frontier province, Pakistan* (Doctoral dissertation, International Islamic University Islamabad, Pakistan).

Mutakinati, L. (2018). *A Research On Critical Thinking Skill, Attitudes, And Career Interests Through Project Based Learnıng in Stem Educatıon Among Japan And Indonesıa Middle School Students*. Shizuoka University Graduate School of Science and Technology Educational Division. Retrieved from https://shizuoka.repo.nii.ac.jp/?action=repository_action_common_download&item_id=11107&item_no=1&attribute_id=31&file_no=3.

Nomura, Y., &Ito, K. (2015). Proposal of a new career educationbased on a teaching method that causes a "stumbling" that can effectively motivate learning by setting individual tasks: Practice at an elementary school in Thailand Evaluation of Teaching Methods through the Bulletin, Bulletin of the Center for Educational Practice, Faculty of Education, Saitama University, *14* , 95-102.

Oh, J. C., Lee, J. H., Kim, J. A., & Kim, J. H. (2012). Development and application of STEAM based education program using scratch-Focus on 6th graders' science in elementary school. *The Journal of Korean association of computer education*, *15*(3), 11-23.

Olivarez, N. (2012). *The Impact of a STEM Program on Academic Achievement of Eighth Grade Students in a South Texas Middle School* (Doctoral dissertation, Texas A&M University-Corpus Christi).

Park, H., Byun, S. Y., Sim, J., Han, H. S., & Baek, Y. S. (2016). Teachers' perceptions and practices of STEAM education in South Korea. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(7), 1739-1753.

Peng, L. W. (2009). *Digital science games' impact on sixth and eighth graders' perceptions of science* (Doctoral dissertation, Ohio University).

Polat, S., & Ay, O. (2016). Meta-Sentez: Kavramsal Bir Çözümleme [Meta-Synthesis: A Conceptual Analysis.]. *Journal of Qualitative Research in Education*, 52-64.

Pozarski Connolly, C. J. (2017). *Evaluating the Effectiveness of Project ReCharge: A STEM Based Energy Efficiency Curriculum* (Doctoral dissertation).

Rabalais, M. E. (2014). *STEAM: A national study of the integration of the arts into STEM instruction and its impact on student achievement*. University of Louisiana at Lafayette.

Rusman, E., Ternier, S., & Specht, M. (2018). Early second language learning and adult involvement in a real-world context: Design and evaluation of the "ELENA Goes Shopping" mobile game. Journal of Educational Technology & Society, 21(3), 90-103.

Sáinz, M., & Müller, J. (2017). Gender and family influences on Spanish students' aspirations and values in stem fields. International Journal of Science Education, 40(2), 188-203.

Shin, S., Rachmatullah, A., Roshayanti, F., Ha, M., & Lee, J. K. (2018). Career motivation of secondary students in STEM: A cross-cultural study between Korea and Indonesia. International Journal for Educational *and Vocational Guidance*, *18*(2), 203-231.

Suwarma, I. R. (2014). A Research On Stem Education Theory And Practices Method In Japan And Indonesia Using Multiple Intelligences Approach.Retrieved from https://shizuoka.repo.nii.ac.jp/?action=pages_view_main&active_action=repository_view_main_item_detail&item_id=7088&item_no=1&page_id=13&block_id=21.

Tamayama, S., Ozawa, Y., Sakamato, K., Miura, T., Morikawa, Y., Muko, H., Sumida, M., Nakamoto, G., Ohashi, A., Hizume, M., Nakamura, Y., Sano, S., Yoshimura, N., Onishi, Y. (2016). Development and Practice of a Teaching Material Focusing Regional Industry for STEM Education. Ehime University Bulletin of the Faculty of Education, 63, 161-167.

Taylor, B., McLean, C. M., Duncan, A., Jayasuriya, A., Dodd, R., & Whiting, T. (2018).A pilot initiative on improving students' task value perceptions of high school mathematics through practical STEM interventions.In *29th Australasian Association for Engineering Education Conference 2018 (AAEE 2018)* (p. 670).Engineers Australia.

Timms, M., Moyle, K., Weldon, P. R., & Mitchell, P. (2018). Challenges in STEM Learning in Australian Schools. Policy Insights, Issue# 7. Australian Council for Educational Research.

Tippett, C. D., & Milford, T. M. (2017). Findings from a pre-kindergarten classroom: Making the case for STEM in early childhood education. *International Journal of Science and Mathematics Education*, *15*(1), 67-86.

Tomoki, S. (2017). The concept of creativity in a learning environment integrated with STEM. In Japan Society for the Study of Science Education 41 (pp. 67-70).

Tran, Y. (2018). Computer programming effects in elementary: Perceptions and career aspirations in STEM. *Technology, Knowledge and Learning*, *23*(2), 273-299.

Ulutan, E. (2018). *Dünyada Eğitim Trendleri Ve Ülkemizde Stem Öğrenme Etkinlikleri: Meb K12 Okullari Örneği[Education Trends in the World and Stem Learning Activities in Turkey: The Case of Meb K12 Schools]*.Retrieved fromhttps://yegitek.meb.gov.tr/meb_iys_dosyalar/2018_11/05144830_Ezgi.pdf.

Vennix, J., Den Brok, P., &Taconis, R. (2017). Perceptions of STEM-based outreach learning activities in secondary education. *Learning Environments Research*, *20*(1), 21-46.

Vossen, T. E., Henze, I., Rippe, R. C. A., Van Driel, J. H., & De Vries, M. J. (2018). Attitudes of secondary school students towards doing research and design activities. *International Journal of Science Education*, *40*(13), 1629-1652.

Yurdakul, B. (2005). Bilişötesi ve Yapilandirmaci Öğrenme Çevreleri [Metacognitive and Constructivist Learning Environments]. *Educational Administration in Theory and Practice*, 279-298.