Journal of STEAM Education
Journal of Science, Technology, Engineering, Mathematics and Art Education
2024, Jan. (Issue: 1, Volume: 7)

Evaluation of Science Teacher Candidates' Metaphorical Perceptions Regarding STEM Concept

Fatma Bulut-Atalar[1] Mustafa Ergün[2]

Research Article

Article History

Received: 29 Oct. 2023

Received in revised form:

24 Dec. 2023

Accepted: 30 Dec. 2023

Published: 30 Jan 2024

ABSTRACT

This study aimed to examine the metaphorical perceptions of science teacher candidates regarding STEM. The ninety-two science teacher candidates in the 3rd grade received four-week STEM Implementation Training, which included STEM activities. In line with the answers given to the metaphor before and after the training, opinions about STEM were determined and possible changes were examined. Phenomenology, one of the qualitative research designs, is present in the study. Metaphors were analyzed using the content analysis technique. To ensure the reliability of the research, the determined codings were checked by two field experts and the results were evaluated by reaching a consensus. The metaphors collected in the study were matched under categories with a reliability of 0.87. In the study, it was determined that one-third of the participants had never heard of STEM before. However, STEM is mostly associated with metaphors such as "life, game, scientific game, invention, universe, imagination, machine, transition from abstract to concrete, science, puzzle, textbook, different perspective and dream". While 41 different metaphors were produced for STEM before the training, this number increased to 50 after the training. At the end of the training, participants' negative metaphors about STEM were replaced by positive ones, four of the categories remained the same and six categories changed. In the study, it was concluded that ideas about the purpose of STEM were formed.

Keywords: STEM, metaphorical perception, teacher candidates

[1] Faculty of Education, Ondokuz Mayis Üniversity, Turkey bulutatalar@gmail.com, 0000-0002-4090-9548

[2] Faculty of Education, Ondokuz Mayis Üniversity, Turkey, mergun@omu.edu.tr, 0000-0003-4471-

Bulut-Atalar, F. & Ergün, M. (2024). Evaluation of science teacher candidates' metaphorical perceptions regarding STEM concept. *Journal of STEAM Education, 7*(1), 39- 54. https://doi.org/10.55290/steam.1382742

INTRODUCTION

Using, technology in the classroom has become increasingly important in modern education. Technology has the potential to make learning more interactive, engaging and fun for students. It provides opportunities for multimedia presentations, interactive simulations, educational games and virtual reality experiences that can attract students' attention and increase their motivation to learn (Uşun, 2004; Şimşek, 2015). Technology provides interactive and engaging learning materials that attract students' attention. With the use of visual and auditory elements, learning experiences become more engaging and increase student engagement (Alpar et al., 2007; Yumuşak & Aycan, 2002). Technology can personalize learning to suit different learning styles, needs and speeds. It provides students with the opportunity to deliver content that meets their individual goals and can adapt the learning process to the needs of the student. Technology improves students' collaborative skills and communication abilities. With the development of technology, digital educational games have gained importance (Akpınar, et al., 2005; Özer, 2020).

It is known that as a significant part of economic development comes from technological innovation, it is important to train engineers and science experts and to spread science and technology literacy (Miaoulis, 2009). Serious issues such as the economic competition between countries, the development of industry and technology, and the gradual decrease in non-renewable energy resources have necessitated changes in the knowledge and skills that people need to acquire both in business life and in our daily lives (Roehrig et al., 2012). Providing students with 21st-century skills such as creativity, innovation, entrepreneurship, informed career choice and adaptability to business life is crucial for strengthening the country's economy and social infrastructure (MoNE, 2015).

The skills that students are expected to acquire with the STEM approach are in line with 21st-century skills (Bybee, 2010; Sanders, 2009). The four branches of STEM (Science, Technology, Engineering and Mathematics), especially science and mathematics, have been important for all students' academic careers (White, 2014). STEM was first used as SMET (Sanders, 2009), and is a work of the National Science Foundation (NSF) (White, 2014).

Thanks to STEM, individuals are expected to gain qualities such as developing problem-solving skills, increasing their creativity and production (Bybee, 2013; Tezel & Yaman, 2017). STEM paves the way for entrepreneurship on a global basis and builds bridges between school, business and society (Thomas, 2014). By transforming the information taught at school into designs and products in engineering and technological fields, the information will be learned permanently, and the purpose of STEM will be achieved (Timur & Inancli, 2018). STEM also increases students' interest in science lessons (Yamak et al., 2014). STEM activities before university also increase students' interest in professions related to STEM fields (Edzie, 2014).

The STEM Education Report published by the Ministry of Education includes topics such as the importance of STEM, a new model proposal, teacher training, establishment of STEM Education Centers, conducting research, updating curriculum, and improving conditions in schools (MoNE, 2016).

In the Science Curriculum published in 2018, STEM integrated studies were carried out in the curriculum by including the Science, Engineering and Entrepreneurship Applications section in the 4th, 5th, 6th, 7th and 8th grades. STEM to be acquired by students is implicitly included in the achievements in the curriculum, and the products created by applications are expected to be exhibited in the lessons (MoNE, 2018). Secondary school students think that STEM activities benefit them in many ways, that they want to improve themselves more in these areas, and that STEM activities should be included in classes (Gokbayrak & Karisan, 2017). Removing the boundaries between disciplines will increase the value of STEM by reflecting the positive effects of the fields in which students are more interested in other fields (Gulhan & Sahin, 2020).

Revealing the perceptions of teachers and teacher candidates towards STEM will be important to identify existing misconceptions and correct them before it is too late. In this study, teacher candidates are enabled to express their current perceptions and explain abstract concepts more easily by concretizing them, thanks to the metaphors and related explanations they produce about STEM (Zengin & Ugras, 2019). What is meant by the concept of metaphor is the explanation of a concept, phenomenon, or event by comparing it to another concept, phenomenon, or event (Oxford et al., 1998). Since the meaning of a well-known situation is transferred to an unknown situation in metaphor, this method is effective in explaining a new phenomenon (Cerit,2008). In the field of education, metaphors can be used to express some concepts, perceptions and attitudes that are desired to be understood in more detail and clearly (Dos, 2010). Process-oriented evaluations are preferred in STEM-related studies increasing in Turkey (Idin, 2017). It is important to increase the training that includes STEM-related applications and expand the scope of education (Eroglu & Bektas, 2016). It is stated that metaphors are used in a minority of STEM studies conducted with prospective teachers (Ergun & Kiyici, 2019). Considering these evaluations in the literature, it is thought that the study will contribute to the literature.

This study aimed to determine the metaphorical perceptions of candidate science teachers about the concept of STEM. Participants were given a four-week applied training based on STEM activities. Data were collected with a metaphor sentence before and after the training. In this way, the changes between the metaphorical perceptions of the participants before and after the STEM implementation training were analyzed. In this context, the following questions were sought to be answered in the research:

1) Which metaphors explain the concept of "STEM" before the applied education? In which categories are these metaphors grouped?

2) Which metaphors explain the concept of "STEM" after the applied training? In which categories are these metaphors grouped?

3) Were changes observed in metaphors and categories before and after the applied training?

METHOD

The research has the nature of phenomenology, which is one of the qualitative research designs. The qualitative method is aimed to reflect what individuals experience from the participant's perspective (Merriam, 2013). In phenomenology, existing phenomena in individuals are revealed in detail by conceptualizing the data and revealing themes that can describe the phenomenon (Yildirim & Simsek, 2011). In this study, this design was preferred with the aim of examining the participants' current STEM perceptions and their changes after the training in depth.

Participants

Participants in the study were determined according to easily accessible case sampling, one of the purposeful sampling methods, and the principle of volunteering. This sampling method speeds up the study by making it easier to determine the study group (Yildirim & Simsek, 2011). 92 science teacher candidates studying in the 3rd grade at the faculty of education of a state university participated in the research.

Data collection and analysis

In the study, “What are the metaphorical perceptions of science teacher candidates regarding STEM before and after the STEM Implementation Training?” STEM metaphor sentence was used to get an answer to the problem sentence. With this sentence, participants were asked to define STEM with a metaphor and state the reason for the metaphor they used. For this purpose, prospective teachers asked, “STEM is like …………. Because …………." and the sentence has been completed. With the metaphor sentence, the participants express their feelings and thoughts freely (Creswell, 2008). Participants received a four-week STEM Implementation Training, which included STEM activities. The specified metaphor sentence was applied to the participants before and after the training and data was collected at two different times.

The four STEM activities carried out in the implemented education were based on the subject areas of Living Things and Life, Physical Phenomena, Matter and Nature, Earth and Universe in the Science Curriculum (2018). Artificial Hand, Let's Build Our Bridge, Inflating a Balloon Without Blowing, Solar System Model activities were carried out with design-based learning model stages. In this model, the construction stages of the activities are as follows (Penner et al., 1997; Penner et al., 1998):

- Dividing the participants into groups.
- Explanation of the researcher's role in the design to be made in the activity.
- Making design plans by groups.
- The researcher initiates the class discussion and participants convey their thoughts.
- Making model presentations by taking the participants through testing, evaluation and review stages.
- The researcher conducts studies on STEM through the models made.

The data collected in the study were analyzed in the stages of coding, sorting, category development, ensuring validity and reliability, data recording and interpretation. In the study, metaphors were analyzed using the content analysis technique. The process of identifying, quantifying, and interpreting recurring themes, issues, and ideas in qualitative data is known as content analysis (Silverman, 2000). The metaphors created by the prospective teachers were first sorted alphabetically and coded. Papers that did not provide a justification in the metaphor sentence and did not make a connection were eliminated. The metaphors in the papers were examined, the main categories to which they would be associated were created and interpreted. The relationship between them was analyzed by determining how the metaphor was conceptualized and what the common features of the metaphors produced were. To ensure the reliability of the research, the determined codings were checked by two field experts and the results were evaluated by reaching a consensus. In the data analysis, it was determined that the metaphors collected were placed in the categories with a reliability of 0.87 by using the reliability formula of consensus and disagreement (Reliability Formula= Consensus / Consensus + Disagreement) (Miles & Huberman, 1994).

RESULTS

Metaphorical perceptions of the concept of STEM before the training

Science teacher candidates' metaphors regarding the concept of STEM were determined before the practical training. 31 out of 92 participants stated that they had never heard of STEM before. The metaphors they created about STEM are given with their frequency in Table 1. As can be seen in the table, a total of 41 metaphors were mentioned about STEM and 30 of these metaphors were produced by only one participant. It is seen that teacher candidates associate STEM with the metaphors of "life (8), games (3), creativity (3), puzzle (2), reality (2), use in daily life (2), invention (3), machine (2), technology (2), technology design course (2), experience (2)".

In line with the explanations given to the metaphors related to STEM, 9 categories were formed. Frequency and percentage values of the categories are given in Table 2. Teacher candidates explained STEM as being like life and in all areas of life with a rate of 13.0%, accommodating many fields with a rate of 12.0%, producing products with a rate of 5.4%, providing permanent learning with a rate of 4.3%, being both fun and instructive and being design-oriented, making the individual active and increasing reality with a rate of 3.3%, and being a hassle with a rate of 2.2%. The 17 metaphors that could not be placed in any category are not given in the table.

Journal of STEAM Education
Journal of Science, Technology, Engineering, Mathematics and Art Education
2024, Jan. (Issue: 1, Volume: 7)

Table 1. Frequency values of metaphors produced for STEM before applied training

No	Metaphor Name	Frequency(f)	No	Metaphor Name	Frequency(f)
1	life	8	22	dreams	1
2	invention	3	23	explore	1
3	games	3	24	book	1
4	creativity	3	25	reinforce	1
5	crossword	2	26	amusement park	1
6	reality	2	27	mechatronics	1
7	using in daily life	2	28	model creation	1
8	machine	2	29	engineering and science	1
9	technology	2	30	students	1
10	technology design course	2	31	problem-solving methods	1
11	experience	2	32	draw a picture	1
12	horse carriage	1	33	robot	1
13	baby	1	34	virtual world	1
14	composite	1	35	exams	1
15	computer	1	36	stem	1
16	science	1	37	designing	1
17	scientists	1	38	puzzle	1
18	chameleon	1	39	auxiliary resources	1
19	children	1	40	cooking	1
20	sock ripper	1	41	smartphone	1
21	activities	1		Total	61

Table 2. Categories obtained from the metaphors produced for STEM before the applied training

Category	Frequency (f)	Percentage (%)
To be like life and to be in all areas of life	12	25,0
Accommodating many fields	11	22,9
Producing a product	5	10,4
Providing permanent learning	4	8,3
Being both fun and instructive	4	8,3
Being design-oriented	4	8,3
Making the individual active	3	6,3
Increasing reality	3	6,3
Being a hassle	2	4,2
Total	48	100

The metaphors in the STEM categories are given in Table 3 with their frequency counts. The category indicates that STEM accommodates many fields; mechatronics field, stem, science, baby, cooking, compound, robot, computer, machine, engineering and science metaphors. In the category indicating that STEM makes the individual active, there are activity and technology design course metaphors. In the category indicating that STEM increases reality, there are reality and virtual world metaphors. In the category indicating that STEM is like life and in all areas of life; there are metaphors of using in daily life, life and experience. In the category indicating that STEM provides permanent learning, there are book, reinforcing the subject, student and auxiliary resource metaphors. In the category indicating that STEM is both fun and instructive, there are game and amusement park metaphors. In the category indicating that STEM is design-oriented, there are metaphors of designing and creativity. In the category indicating that STEM is a hassle, there are crossword metaphors. In the category that indicates producing a product, there are metaphors of scientist, invention and explore.

Table 31. Frequency values of metaphors in STEM categories before applied training

Metaphor	Frequency (f)	Category
machine	2	accommodates many fields
stem	1	
science	1	
baby	1	
cooking	1	
compound	1	
robot	1	
computer	1	
mechatronics field	1	
engineering and science	1	
technology design lesson	2	making the individual active
activity	1	
reality	2	increases reality
virtual world	1	
life	8	be like life and be in all areas of life
use in daily life	2	
experience	2	
book	1	provides permanent learning
reinforce	1	
student	1	
auxiliary resources	1	
games	3	being both fun and instructive,
auxiliary resources	1	
creativity	3	design-oriented
designing	1	
crossword	2	being a hassle
invention	3	producing a product
scientists	1	
explore	1	
Total	48	

Metaphorical perceptions of the concept of STEM after the training

Teacher candidates' metaphors about STEM after the training were determined. Of the 92 participants, the papers of 4 people who did not fill in the metaphor sentence were excluded from the analysis, and the remaining 88 data were analyzed. The frequency of the participants' metaphors about STEM is shown in Table 4. A total of 50 metaphors were mentioned about STEM and 38 of these metaphors were produced by only one participant. STEM was mostly associated with the metaphors of "life (14), game (5), scientific game (4), invention (5), universe (3), imagination (3), machine (3), from abstract to concrete (3), science (3), puzzle (2), book (2), different perspective (2) and dream (2)".

Table 4. Frequency values of metaphors produced for STEM after the training

No	Metaphor Name	Frequency (f)	No	Metaphor Name	Frequency (f)
1	life	14	26	rainbow	1
2	invention	5	27	imaginary	1
3	game	5	28	life and technology	1
4	scientific game	4	29	sculptor	1
5	science	3	30	making a cake	1
6	universe	3	31	discoveries	1
7	imagination	3	32	book	1
8	machine	3	33	labyrinth	1
9	from abstract to concrete	3	34	lego	1
10	crossword	2	35	making a model	1
11	textbook	2	36	mathematics	1
12	different perspective	2	37	model creation	1
13	dream	2	38	ocean	1
14	mother	1	39	play dough	1
15	collision of atoms	1	40	pizza	1
16	granny braid	1	41	problem-solving	1
17	scientist	1	42	project	1
18	building construction	1	43	robot	1
19	cartoon	1	44	designing	1
20	children	1	45	technology design	1
21	all-round development	1	46	seed	1
22	iron	1	47	hope	1
23	studying	1	48	creativity	1
24	entertainment	1	49	cooking	1
25	activity	1	50	fruit produced	1
				Total	88

In line with the explanations given to the metaphors related to STEM, 10 categories were created. Frequency and percentage values of the categories are given in Table 5. STEM was explained as 20.5% creating products and models, 17.0% being like life and being in all areas of life, 12.5% enhancing creativity, 10.2% developing the individual in many ways and accommodating many fields, 8.0% relying on and developing imagination, 5.7% providing effective and permanent learning, being open to development, 2.3% generating different ideas and translation into function. Apart from these, 5 metaphors (5.7%) that could not be placed in any category are not given in the table.

Table 5. Categories obtained from the metaphors produced for STEM after the training

Category	Frequency (f)	Percentage (%)
Product and model creation	18	21,7
Being like life and being in all areas of life	15	18,1
Enhancing creativity	11	13,3
Developing the individual in many ways	9	10,8
Accommodating many fields	9	10,8
Relying on and developing the imagination	7	8,4
Providing effective and permanent learning	5	6,0
Being open to development	5	6,0
Generating different ideas	2	2,4
Translation into function	2	2,4
Total	83	100

The metaphors in the STEM categories are given in Table 6 with their frequency counts. In the category of product and model creation; model creation, problem-solving activity, designing, building construction, crossword, invention, imagination, life and technology, sculptor, invention, discovery, model making, technology design lesson and seed metaphors were found. In the category of STEM being like life and being in all areas of life; there are life and mathematics metaphors. In the category of enhancing creativity, there are metaphors of science, scientist, scientific game, imagination, book, and creativity. In the category of developing the individual in many ways, there are metaphors such as collision of atoms, children, all-round development, activity, and game. In the category of accommodating many fields; science, making cake, machine, pizza, project, robot, and cooking metaphors are included. In the category of relying on and developing imagination, there are the metaphors of collision of atoms, cartoon, rainbow, imagination, and lego. In the category of providing effective and permanent learning; there are textbook, from abstract to concrete metaphors. In the category of being open to development, there are grandmother's braid, universe and ocean metaphors. In the category of generating different ideas; there is a different perspective metaphor. In the category of translation into function; there are iron and play dough metaphors.

Table 6. Frequency values of metaphors in STEM categories after applied training

Metaphor	Frequency (f)	Category
invention	4	Product and model creation
crossword	2	
designing	1	
building construction	1	
problem-solving activity	1	
invention	1	
imagination	1	
life and technology	1	
sculptor	1	
model creation	1	
discovery	1	
model making	1	
technology design lesson	1	
seed	1	
life	14	Being like life and being in all areas of life
mathematic	1	
scientific game	4	Enhancing creativity
imagination	2	
science	2	
scientist	1	
book	1	
creativity	1	
game	5	Developing the individual in many ways
children	1	
all-round development	1	
activity	1	
collision of atoms	1	
machine	3	Accommodating many fields
making cake	1	
science	1	
pizza	1	
project	1	
robot	1	
cooking	1	
imagination	3	Relying on and developing the imagination
cartoon	1	
rainbow	1	
collision of atoms	1	
lego	1	
from abstract to concrete	3	Providing effective and permanent learning
textbook	2	
universe	3	Being open to development
grandmother's braid	1	
ocean	1	
different perspective	2	Generating different ideas
iron	1	Translation into function
play dough	1	
Total	83	

DISCUSSION

In the study, STEM was introduced to science teacher candidates through a four-week STEM Implementation Training (SIT) in which activities were prioritized. Participants' metaphorical perceptions of the concept of STEM before and after SIT were determined and current changes were analyzed.

Before SIT, 31 out of 92 teacher candidates (34%) could not complete the metaphor sentence by stating that they had never heard of STEM before. This is thought to be because there is no course on STEM in the participants' universities. In addition, those who had heard about STEM before were mentioned very briefly in some courses or learned about it in seminars they attended. Studies have shown that approximately half of science, mathematics and informatics teachers have never heard the term STEM before (Cevik, 2017).

Before the SIT, 43 metaphors were identified. The frequency of 31 of these metaphors was 1. Out of 61 metaphor sentences, half of them defined STEM with different words. STEM was mostly associated with the metaphors "life, game, creativity, puzzle, reality, using in daily life, invention, machine, technology, technology design course, experience". It was mentioned that STEM is like life in general and is in all areas of life, includes many fields, produces products, provides permanent learning, is both fun and instructive, is design-oriented, makes the individual active, increases reality, and is challenging.

After the SIT, participants stated a total of 50 metaphors about STEM. The frequency of 38 of these metaphors was 1. STEM was mostly associated with the metaphors "life, game, scientific game, invention, universe, imagination, machine, transition from abstract to concrete, science, crossword, textbook, different perspective and dream". However, it was concluded that teacher candidates did not have a negative perception of STEM.

With the training provided to the participants, the number of metaphors that emerged increased as each participant formed a metaphor perception about STEM. The number of categories created in both processes increased from nine to ten. While four of the categories remained the same (being like life and in all areas of life, accommodating many fields, product and model creation, providing effective and permanent learning), 6 categories changed.

The prominent features of STEM in general were very similar in both analyses. The reason for this is thought to be that the prior knowledge of those who have heard about STEM is similar to the information given in the training. The fact that the category of being a hassle before the training was not present at the end of the training and the emergence of the categories of creativity, imagination, being open to development, generating different ideas and functionality shows that the participants had positive and purposeful ideas about STEM.

The reason why the metaphors after the training were gathered in the categories of product/model creation and life is thought to be that four different STEM activities were carried out by the participants during the training and a product was created. In addition, it is thought that the feature of developing creativity is related to the fact that the participants were offered a variety of materials during the activity and made their designs and models for the specified targets.

There are studies in the literature that show similarities with the metaphors and categories found in the research. Teacher candidates consider STEM as an interdisciplinary approach that moves forward, provides socialization and communication (Gokce & Yenmez, 2020). It was determined that teacher candidates perceived STEM as an interdisciplinary approach that provides learning by doing and experiencing in the process of creating new products and aims to raise individuals who produce solutions to problems (Ergun & Kiyici, 2019; Kizilay, 2018; Gomleksiz & Yavuz, 2018).

The metaphors that a design is created with STEM, life and design-creativity metaphors are used, STEM is process-oriented and product-oriented metaphors are stated (Aladak et al., 2018; Bozkurt-Altan et al., 2016; Zengin & Ugras, 2019). The expression of STEM as an approach that utilizes knowledge in daily life, contributes to the solution of daily problems and develops the skills required by the age in individuals is in parallel with the metaphors mentioned in the study.

The metaphors produced by primary school teacher candidates for STEM disciplines were science-life, doing science, experiment-laboratory, need-necessity, development-change, innovation, mathematics, design-creativity, mathematics as a pile of numbers, mathematics as a process, mathematics as a course that requires logic, and mathematics as a fun course (Zengin & Ugras, 2019).

Kazu and Isik (2020) categorized science teachers' metaphors about STEM according to the skills expected from individuals in the 2018 World Economic Forum's Future of Jobs Report. The categories that produced the most metaphors were "Leadership and Social Impact", "Complex Problem Solving / Reasoning, Problem Solving and Understanding", "Analytical Thinking and Innovation / Creativity, Originality and Sociability", and the categories that produced the least metaphors were "Emotional Intelligence", "Technology Design and Programming" and "Critical Thinking and Analysis". Along with the research, it is seen in the literature that teacher candidates’ perceptions towards STEM are positive (Acar, Ecevit, Buyuksahin,2020; Gokce & Yenmez, 2020; Ergun & Kiyici, 2019, Gomleksiz & Yavuz, 2018).

RECOMMENDATIONS

Based on the results of the study, important recommendations are given below.

- Increasing the number of studies to determine the metaphorical perceptions of teacher candidates about STEM is thought to be important in terms of concretizing the data about how much STEM education is understood.
- It is thought that it will be important to provide courses in universities and to disseminate STEM education in order for teacher candidates to learn STEM education in their faculties.
- In addition, it is thought that interdisciplinary cooperation is important through the cooperation of engineering fields with faculties of education.

- To better understand STEM education and to reveal its integrated, creative and productive aspects, it is thought that it would be more efficient to introduce it through applied trainings.

DECLARATIONS

Data Availability: Data is available upon request to the author.

Ethical Rules: In this research, the ethics committee approval notification document containing the eligibility decision for the research was received from the Ondokuz Mayis University Social Sciences and Humanities Ethic Committee (Date: 02.05.2018, No: 2018/162). All ethical procedures were followed during and after completing the study.

Authors Contributions: All the work was done by the author.

Conflict of Interest: There is no conflict of interest.

Acknowledge: This study was prepared based on a part of the thesis named ‘ Assesssment of an educational practice for increasing the STEM awareness and attitude of science teacher candidates’.

REFERENCES

Aladak, K.B.D., Zorluoglu, S.L. & Yapucuoglu, M.D. (2018). STEM: öğretmenlerin metaforik algıları [STEM: Metaphorical perceptions of teachers]. *Akdeniz Egitim Arastirmalari Dergisi*, *12*(26), 80-98. https://doi.org/10.29329/mjer.2018.172.5

Acar, D., Ecevit, T., & Buyuksahin, Y. (2020). Fen bilimleri öğretmen adaylarının STEM eğitimine yönelik metaforik algıları [Pre-Service science teachers’ metaphoric perceptions toward STEM education] *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi*, *21*(3), 1839-1873. https://doi.org/10.29299/kefad.768397

Bozkurt-Altan, E., Yamak, H. & Bulus-Kirikaya E. (2016). FeTeMM eğitim yaklaşımının öğretmen eğitiminde uygulanmasına yönelik bir öneri: tasarım temelli fen eğitimi [A proposal of the STEM education for teacher training: design based science education]. *Trakya Üniversitesi Eğitim Fakültesi Dergisi*, *6*(2), 212-232.

Bybee, R. W. (2010). Advancing STEM education: a 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30-35.

Bybee, R. W. (2013). *The case for STEM education: challenges and oppurtunities.* NSTA Press.

Cerit, Y. (2008). Öğretmen kavrami ile ilgili metaforlara ilişkin öğrenci, öğretmen ve yöneticilerin görüşleri [Students, teachers and administrators’ views on metaphors with respect to the concept of teacher] *Türk Eğitim Bilimleri Dergisi*, *6*(4), 693-712.

Creswell, J.W. (2008). *Educational Research planning, conducting, and evaluating qualitative research* (3rd Ed.). NJ:Pearson Education.

Cevik, M. (2017). Content analysis of STEM-focused education research in Turkey. *Türk Fen Eğitimi Dergisi, 14*(2), 12-26. https://doi.org/10.12973/tused.10195a

Dos, I. (2010). Aday öğretmenlerin müfettişlik kavramına ilişkin metafor algıları [Metaphoric perceptions of candidate teachers to the concept of inspectors]. *University of Gaziantep Journal of Social Sciences*, *9*(3), 607-629.

Edzie, R.M. (2014). Exploring the factors that influence and motivate female students to enroll and persist in collegiate STEM degree programs: A mixed methods study. Ph.D. theses, University of Nebraska, Lincoln.

Ergun, A., Kiyici G. (2019). Fen bilgisi öğretmeni adaylarının STEM eğitimine ilişkin metaforik algıları [Metaphorical perceptions of science course teacher candidates of STEM education]. *Kastamonu Eğitim Dergisi*, *27*(6), 2513-2527. https://doi.org/10.24106/kefdergi.3405

Eroglu, S., Bektas, O. (2016). STEM eğitimi almış fen bilimleri öğretmenlerinin stem temelli ders etkinlikleri hakkındaki görüşleri [Ideas of science teachers took STEM education about STEM based activities]. *Eğitimde Nitel Araştırmalar Dergisi*, *4*(3), 43-67.

Gokbayrak, S., Karısan, D. (2017). Altıncı sınıf öğrencilerinin fetemm temelli etkinlikler hakkındaki görüşlerinin incelenmesi [Exploration of sixth grade students' views on STEMM based activities]. *Alan Eğitimi Araştırmaları Dergisi*, *3*(1), 25-40.

Gokce, S., & Aydoğan Yenmez, A. (2020). Pre-service teachers' metaphoric perceptions regarding STEM education. *International Journal of Education Technology and Scientific Researches*, *5*(12), 1133-1161.

Gulhan, F., & Sahin, F. (2020). Ortaokul öğrencilerinin STEAM (bilim, teknoloji, mühendislik, matematik, sanat) alanlarıyla ilgili algılarının metaforlar aracılığıyla belirlenmesi [The determination of secondary school students' perceptions about STEAM fields via metaphors]. *Düzce Üniversitesi Sosyal Bilimler Dergisi*, *10*(1), 131-148.

Gomleksiz, M. N., & Yavuz, S. (2018). *Fen bilgisi öğretmen adaylarının STEM eğitimine yönelik metaforik algıları.* E R P A International Congresses on Education, İstanbul, Türkiye.

Idin, Ş. (2017). Örnek ve uygulama destekli fen öğretiminde disiplinler arası beceri etkileşimi. E. Kandemir (ed.), *STEM Yaklaşımı ve Eğitime Yansımaları* (pp. 255-282). Pegem Akademi.

Kazu, İ. Y. & Isik, S. N. (2020). The metaphorical perceptions of science teachers regarding STEM education. *Eğitim Kuram ve Uygulama Araştırmaları Dergisi, 6*(3), 359-372.

Kizilay, E. (2018). STEM alanlarının birbirleri ile ilişkisi hakkında fen bilgisi öğretmen adaylarının görüşleri [Pre-service science teachers' opinions about the relationship of stem fields]. *Eğitim ve Toplum Araştırmaları Dergisi*, *5*(2), 174-186.

Ministry of National Education [MoNE] (2015). Milli Eğitim Bakanlığı 2015-2019 yılı stratejik planı [Ministry of National Education 2015–2019 strategic plan]. http://sgb.meb.gov.tr/meb_iys_dosyalar/2015_09/10052958_10.09.2015sp17.15imzasz.pdf

Ministry of National Education [MoNE] (2016). STEM eğitimi raporu [STEM education report]. Innovation and Educational Technologies General Directorate. Ankara. https://yegitek.meb.gov.tr/STEM_Egitimi_Raporu.pdf.

Ministry of National Education [MoNE]. (2018). İlköğretim kurumları fen bilimleri dersi öğretim programı [Science course curriculum].

Merriam, S. B. (2013). *Nitel araştırma: desen ve uygulama için bir rehber* [Qualitative Research: A Guide to Design and Implementation] (3. Baskıdan Çeviri, Çeviri Editörü: S. Turan). Nobel Yayın Dağıtım.

Miaoulis, I. (2009). Engineering the K-12 curriculum for technological innovation. IEEE-USA Today’s Engineer Online. http://www.todaysengineer.org/2009/Jun/K-12-curriculum.asp

Miles, M.B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook.* Sage.

Oxford, R. L., Tomlinson, S., Barcelos, A., Harrington, C., Lavine, R. Z., Saleh, A. & Longhini, A. (1998). Clashing metaphors about classroom teachers: toward a systematic typology for the language teaching field. *System*, *26*, 3-50. https://doi.org/10.1016/S0346-251X(97)00071-7

Penner, D., Giles, N., Lehrer, R., & Schauble, L. (1997). Building functional models: designing an elbow. *Journal of Research in Science Teaching, 34*, 125–143.

Penner, D. E., Lehrer, R., & Schauble, L. (1998). From physical models to biomechanical systems: a design-based modeling approach. *Journal of the Learning Sciences*, *7*(3&4), 429-449.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, *112*, 31-44.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4), 20-26.

Silverman, D., (2000). *Doing qualitative research: a practical handbook*. SAGE Publication.

Tezel, Ö. & Yaman, H. (2017). FeTeMM eğitimine yönelik Türkiye’de yapılan çalışmalardan bir derleme [A review of studies on STEM education in Turkey]. *Eğitim ve Öğretim Araştırmaları Dergisi*, *6*(1), 135-145.

Thomas, T. A., (2014). Elementary teachers’ receptivity to ıntegrated science, technology, engineering, and mathematics (STEM) education in the elementary grades. Ph.D. thesis, University of Nevada, Reno.

Timur, B., Inancli, E. (2018). Fen bilimleri öğretmen ve öğretmen adaylarının STEM eğitimi hakkındaki görüşleri [Science teacher and teacher candidates' opinions about STEM education]. *Uluslararası Bilim ve Eğitim Dergisi*, *1*(1), 48-66.

White, D. W. (2014). What is STEM education and why is it important? *Florida Association of Teacher Educators Journal*, *1*(14), 1-8.

Yamak, H., Bulut, N. & Dundar, S. (2014). 5. sınıf öğrencilerinin bilimsel süreç becerileri ile fene karşı tutumlarına FeTeMM etkinliklerinin etkisi [The impact of STEM activities on 5th grade students' scientific process skills and their attitudes towards science]. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi*, *34*(2), 249-265. https://doi.org/10.17152/gefd.15192

Yildirim, A., & Simsek, H. (2011). *Sosyal bilimlerde nitel araştırma yöntemleri*. (8. baskı). Seçkin Yayıncılık.

Zengin, E. & Ugras, M. (2019). Sınıf öğretmen adaylarının STEM eğitimine ilişkin metaforik algilarinin belirlenmesi [Determination of Class Teacher Candidates Methodoric Perceptions of Stem Education]. *EKEV Akademi Dergisi*, *77*, 57-76.