

## An Examination of Pre-Service Visual Arts Teachers' Metaphorical Perceptions of the STEAM Approach

Yahya Hiçyılmaz<sup>1</sup>

### Abstract

The traditional STEM model, which is primarily centered on engineering, mathematics, and technology, has gradually expanded over time to incorporate the arts, evolving into the STEAM approach. Accordingly, this study aims to examine prospective visual arts teachers' perceptions of the STEAM approach through metaphor analysis. A phenomenological design, one of the qualitative research approaches, was adopted in the study. The participants consisted of 64 prospective teachers enrolled at a public university located in the Eastern Anatolia Region of Türkiye, all of whom completed a four-week STEAM training program and microteaching practices. The data were collected using a metaphor form and analyzed through content analysis. The prospective teachers developed 33 different metaphors regarding the STEAM approach. These metaphors were categorized under six main themes. The prospective teachers described STEAM as a holistic structure in which different components complement one another, using metaphors such as "tree," "rainbow," and "weaving loom." In addition, they emphasized the process-oriented nature of the approach through metaphors like "path," "workshop," and "puzzle"; its capacity to stimulate creativity through "invention" and "dreams"; and its curiosity-arousing character through analogies such as "circus" and "illusionist." In conclusion, it was determined that prospective visual arts teachers perceive STEAM as a bridging model that integrates scientific thinking with the aesthetic and constructive power of art, actively engages students in the learning process, and fosters curiosity. This study provides a significant contribution to STEAM research from the perspective of arts education as well as to the teacher education literature.

### Received:

27 January 2026

### Accepted:

29 March 2026

### Published online:

29 April 2026

### Keywords

STEAM,  
visual arts education,  
prospective teachers,  
metaphor analysis,  
phenomenology

**To cite this article:** Hiçyılmaz, Y. (2026). An Examination of pre-service visual arts teachers' metaphorical perceptions of the STEAM approach. *Journal of STEM Teacher Institutes*, 6(1), 1–9. Retrieved from <https://jstei.com/index.php/jsti/article/view/107>

<sup>1</sup> aVan Yuzuncu Yil University, Faculty of Education, Van, Turkey, ORCID: <https://orcid.org/0000-0003-3453-9998> yahya-04@windowslive.com

## Introduction

The multidimensional and complex nature of contemporary problems renders it insufficient to educate students solely on the basis of scientific and technological literacy. This situation necessitates that creativity, critical thinking, and interdisciplinary problem-solving skills become an integral part of the educational process (Montés et al., 2023; Quigley & Herro, 2016). Developed in response to this need, the STEM (Science, Technology, Engineering, and Mathematics) approach offers a holistic educational paradigm that focuses on real-world problems rather than teaching disciplines in isolation (Montés et al., 2023; Spyropoulou & Kameas, 2023). However, the traditional STEM model, which primarily focuses on engineering-, mathematics-, and technology-based skills, has gradually evolved into the STEAM approach, which also incorporates artistic dimensions (Bassachs et al., 2020; Spyropoulou & Kameas, 2023). Conceptualized by Yakman (2008), STEAM is defined as an interdisciplinary framework in which science and technology are interpreted through engineering and the arts and structured through the language of mathematics. Through this evolution, education has moved beyond a framework restricted to engineering, mathematics, and technology-oriented skills, and has become an interdisciplinary approach emphasizing the understanding and expression of human experience (Bassachs et al., 2020; Spyropoulou & Kameas, 2023; Quigley & Herro, 2016).

Within STEAM, the “A” (Arts) component contributes to the development of a multifaceted perspective necessary for innovation by balancing the convergent thinking characteristic of traditional STEM disciplines with the divergent thinking and creativity inherent in the arts (Filipe, Baptista, & Conceição, 2024; Montés et al., 2023; Mou, 2023). Arts education supports students in developing meaningful relationships with materials, generating diverse solutions through aesthetic practices, and making complex topics more comprehensible (Mou, 2023; Smolin & Preston, 2025). In this context, art is not merely an aesthetic element

in STEAM practices; it is also a significant pedagogical tool that guides inquiry and brings together different forms of knowledge (Filipe, Baptista, & Conceição, 2024; Sanz-Camarero, Ortiz-Revilla, & Greca, 2023; Smolin & Preston, 2025).

In the STEAM approach, the successful integration of the arts component is closely linked to teachers’ professional competencies in this domain. Therefore, the preparation processes of visual arts teachers play a decisive role in the success of STEAM implementations (López, Rodrigues-Silva, & Alsina, 2021; Silva-Hormazábal & Alsina, 2023). In particular, it is essential for preservice visual arts teachers to recognize the role of their own discipline in STEAM integration in order to ensure the effective implementation of this approach within the school setting (Erdoğan, 2020).

In educational research, metaphors are regarded as powerful cognitive tools for revealing individuals’ beliefs, mental models, and perceptions of complex phenomena that may be difficult to articulate directly (Fabian, 2025; Zheng & Song, 2010). Lakoff and Johnson’s (1980) Conceptual Metaphor Theory argues that human thought is inherently metaphorical and that metaphors shape the ways in which individuals conceptualize the world. In examining preservice teachers’ perceptions of a multidimensional approach such as STEAM, metaphor analysis serves as a mirror by reflecting how this process is interpreted by the candidates and what kinds of attitudes are developed (Zheng & Song, 2010).

It is observed that most qualitative studies addressing preservice teachers’ perceptions of STEAM predominantly focus on candidates in science education and primary education programs (Gülhan, 2022; Zengin & Uğraş, 2019). By contrast, the arts domain remains relatively limited within the scope of these studies (Erdoğan, 2020; Sanz-Camarero et al., 2023). Therefore, by uncovering preservice visual arts teachers’ perceptions of the STEAM approach, this study is expected to contribute to arts-based STEAM research as well as to the teacher education literature. Accordingly, this study aims to examine preservice visual arts teachers’ perceptions of the STEAM approach

through metaphor analysis. In line with this aim, the study sought to answer the following research question: “What are preservice visual arts teachers’ metaphorical perceptions of the STEAM approach?”

## Method

### Research Design

In this study, a phenomenological design within the qualitative research approach was adopted in order to examine preservice teachers’ metaphorical perceptions of STEAM in depth. Phenomenology is a research approach that examines how individuals experience a phenomenon and how they make meaning of that experience (Creswell, 2013; Van Manen, 2016). Accordingly, the study investigates preservice teachers’ metaphorical perceptions of the STEAM approach, exploring how they position STEAM and what kinds of analogies they use to describe this approach.

### Participants

The participants of the study consisted of 64 preservice teachers enrolled in the Department of Art Education (Painting) at a public university located in the Eastern Anatolia Region of Türkiye, all of whom volunteered to take part in the research. The participants were selected using criterion sampling, one of the purposive sampling methods. In this method, participants are selected based on their meeting predetermined criteria in a manner that serves the purpose of the study (Patton, 2018). In order to examine preservice teachers’ perceptions of the STEAM approach, the sampling criteria included: being enrolled in the Department of Art Education (Painting), having participated in STEAM-based activities within the visual arts teaching course, having received STEAM education, and volunteering to take part in the study. A total of 64 preservice teachers in their third and fourth years of study who met the specified criteria participated in the research. Of the participants, 64.1% (n = 41) were female and 35.9% (n = 23) were male.

### Data Collection Instrument

In this study, a Metaphor Elicitation Form was used to identify preservice teachers’ perceptions of STEAM through metaphors. Participants were asked to complete the statement “STEAM is like ... because ...”. The forms obtained through this process constituted the primary data source of the study.

### Data Collection Process

In the first stage of the data collection process, preservice teachers were provided with a two-week theoretical introduction to the STEAM approach. During the briefing phase, participants were presented with sample activities illustrating how the STEAM approach can be integrated into educational settings, and key considerations to be taken into account in classroom practices were discussed. In the second stage, preservice teachers carried out microteaching practices based on the STEAM approach. At this stage, they were asked to prepare short instructional plans on how the STEAM approach could be adapted to the visual arts course. Within the scope of the microteaching practices, each participant/group of participants designed a STEAM-based activity and implemented it in the context of the visual arts course. In the third stage, the evaluation process was initiated. During this stage, preservice teachers received feedback on their implementations, and peer assessment was also included. In addition, they discussed the challenges they encountered while implementing the STEAM approach within the context of the visual arts course. In the final stage of the data collection process, a metaphor form was administered in order to identify participants’ perceptions of the STEAM approach through metaphors. This implementation was considered important for revealing how participants, who had completed the briefing and microteaching experiences, made sense of the STEAM approach. Detailed information regarding the data collection process is presented in Figure 1.



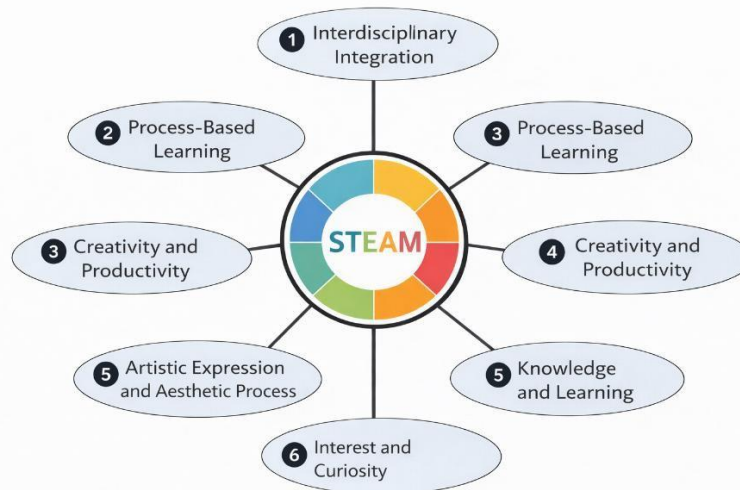
**Figure 1.** Data collection process

### Data Analysis

The qualitative data obtained in the study were analyzed using content analysis. Content analysis is a four-stage process that begins with coding the data and involves identifying and organizing themes, as well as interpreting the findings (Yıldırım & Şimşek, 2013).

Prior to the analysis process, the collected data were reviewed to determine whether they met the specified criteria, and it was found that all participants completed the Metaphor Elicitation Form in accordance with these criteria. To ensure confidentiality, male preservice teachers were coded as EGÖA, and female preservice teachers were coded as KGÖA. During the coding stage, an open coding approach was adopted. The statements of the preservice teachers were examined in detail, and each metaphor obtained was treated as a code. The metaphors were then listed in alphabetical order. Metaphors sharing

similar characteristics or rationales (e.g., “creativity” and “dreams”) were grouped together, and preliminary themes were identified. This process was carried out by two researchers who are experts in visual arts education. Following the coding process, the findings obtained by the researchers were compared. Inter-coder reliability was calculated using the formula proposed by Miles and Huberman (1994), and the agreement rate was determined to be 91%. Any disagreements that emerged during the coding process were resolved by reanalyzing the participants’ statements and, when necessary, consulting a third researcher. In this framework, the process continued until consensus was reached, and the final list of codes and themes was developed. The metaphor themes identified through content analysis are presented in Figure 2.



**Figure 2.** Themes identified through metaphor analysis

**Findings**

Teacher candidates produced a total of 33 metaphors related to STEAM, and these metaphors were grouped under six themes based on their shared characteristics. The themes were identified as interdisciplinary integration, process-based learning, creativity and productivity, artistic expression and the aesthetic process, knowledge and learning, and interest and curiosity. The frequency data

related to the metaphors representing each theme were tabulated, and sample statements reflecting the teacher candidates’ metaphorical perceptions of the concept of STEAM were included in the findings section. The distribution of the metaphors developed by the teacher candidates regarding STEAM across the themes is presented in Table 1.

**Table 1.** Distribution of the metaphors developed by pre-service visual arts teachers regarding the steam approach by themes

Theme	Metaphor	Male (f)	Female (f)	Total (f)
<b>Interdisciplinary Integration</b>	Tree	1	1	2
	Octopus	0	1	1
	Family	1	2	3
	Building	1	0	1
	Rainbow	1	0	1
	Weaving loom	0	1	1
	Life	1	3	4
	Soup	1	0	1
	Tree trunk	0	1	1
	Swiss Army knife	0	1	1
<b>Process-Based Learning</b>	Stroll	1	0	1
	Path	1	0	1
	Puzzle / Jigsaw	1	0	1
	Workshop	1	2	3
	Trial and error	1	1	2
	Construction / Building	1	1	2
	Production process	0	2	2
	Draft	0	1	1
	Sketch	1	1	2
<b>Creativity and Productivity</b>	Creativity	1	2	3
	Dreams	1	3	4
	Invention	1	2	3
	Lightning	0	1	1

	Designing	1	2	3
<b>Artistic Expression and the Aesthetic Process</b>	Drawing / Painting	0	3	3
	Shaping modeling clay	0	1	1
	Book	1	2	3
<b>Knowledge and Learning</b>	Library	0	1	1
	Scientific literacy	0	1	1
	Circus	0	1	1
<b>Interest and Curiosity</b>	Illusionist	0	1	1
	Sky	2	0	2
	Deep-rooted product	0	1	1
	<b>Total</b>	<b>23</b>	<b>41</b>	<b>64</b>

### Interdisciplinary integration

The findings obtained under this theme indicate that the teacher candidates perceive the STEAM approach as a multidimensional structure in which different disciplines complement one another and are integrated toward a common purpose. The metaphors produced suggest that STEAM is perceived not as the mere sum of individual disciplines, but rather as a holistic structure in which each field complements the others. This indicates that interdisciplinary interaction is regarded as a fundamental component of the STEAM approach. Examples of metaphors developed by the teacher candidates that reflect the interdisciplinary integrative nature of STEAM are presented below.

*“STEAM education is like a tree to me because each branch represents a different discipline” (EGÖA2).*

*“STEAM education is like a rainbow to me. Because bringing together multiple disciplines is like colors coming together, and it is exciting” (EGÖA10).*

*“STEAM education is like a weaving loom. Because each thread is a discipline, and if they are not combined properly, the final product cannot emerge” (KGÖA23).*

### Process-Based Learning

The findings obtained within this theme indicate that teacher candidates perceive the STEAM approach as a gradual, constructive learning process that unfolds over time. The metaphors developed reveal that learning is conceptualized not merely as an outcome-oriented structure, but rather as a dynamic and continuously evolving process involving stages such as exploration, trial and error, production,

and development. In this regard, the metaphors stroll, path, and puzzle/jigsaw reflect the perception of learning as a process that progresses step by step and gains meaning through the integration of individual pieces. The metaphors workshop, trial and error, and construction/building indicate that learning is viewed as practice-based, developing through experience and requiring active participation. In addition, the metaphors production process, draft, and sketch reveal that learning is approached as a process that is continually reviewed, refined, and reconstructed. A few examples of the metaphors produced are provided below.

*“STEAM education is like a path to me because it represents an ongoing and continuous form of education” (EGÖA23).*

*“STEAM education is like a stroll to me because I engage with multiple fields while creating a design” (KGÖA3).*

*“STEAM education is like construction because it does not finish immediately; it takes time” (EGÖA11).*

### Creativity and productivity

The findings obtained within this theme indicate that teacher candidates associate the STEAM approach with original thinking, generating new ideas, and creative design processes. The metaphors produced reflect the perception that STEAM provides a learning environment that activates individuals’ imagination, supports innovative thinking, and encourages productivity. In this context, the metaphors creativity and dreams point to the nature of the STEAM approach in encouraging free thinking that goes beyond boundaries, whereas the metaphors invention and lightning

represent sudden realizations and the emergence of innovative ideas. The metaphor designing indicates that STEAM is perceived as an approach in which creative thinking is transformed into tangible outcomes through processes involving planning and production. A few examples of the metaphors produced are presented below.

*“STEAM education is like lightning because it suddenly illuminates the mind and helps us come up with a new idea” (KGÖA16).*

*“STEAM education is like an invention to me because it helps produce things that have not been done before through different disciplines” (EGÖA4).*

*“STEAM education is designing, because you can shape something by designing something different” (KGÖA11).*

**Artistic expression and the aesthetic process**  
The findings obtained within this theme indicate that teacher candidates associate the STEAM approach with artistic production, aesthetic experience, and processes of creative expression. The metaphors produced reflect the perception that STEAM offers a learning environment that enables individuals to express their thoughts and feelings through artistic means while supporting aesthetic sensitivity. In this context, the metaphor drawing/painting reveals that the STEAM approach is integrated with processes of visual expression, creativity, and aesthetic production, whereas the metaphor shaping modeling clay indicates that artistic expression is perceived as a dynamic process that develops through experience, experimentation, and shaping. A few examples of the metaphors produced are presented below.

*“STEAM is like modeling clay. You can shape it into any form you want and create completely new designs” (KGÖA41).*

*“STEAM is like drawing a picture, because over time a picture emerges that reflects your own taste” (KGÖA31).*

*“STEAM is like drawing a picture, because if you do not like it, you can correct the wrong line and draw it again” (KGÖA35).*

Knowledge and learning

The findings obtained within this theme indicate that teacher candidates associate the STEAM approach with processes of knowledge acquisition, learning, and scientific thinking. The metaphors produced reflect the perception that STEAM provides a learning environment that facilitates access to knowledge, supports learning, and enhances scientific literacy. In this context, the metaphors book and library reveal that the STEAM approach is associated with processes of accessing knowledge, organizing information, and structuring learning, whereas the metaphor scientific literacy indicates that STEAM is perceived as an approach that supports skills such as critical thinking, inquiry, and scientific understanding. A few examples of the metaphors produced are presented below.

*“STEAM education is like a library to me because it aims to educate individuals who are innovative, solution-oriented, and equipped with strong communication skills” (KGÖA15).*

*“STEAM education is like a book to me because it contains many things that I am looking for” (KGÖA1).*

*“STEAM education is like scientific literacy to me because it broadens our horizons by bringing five disciplines together” (EGÖA21).*

**Interest and curiosity**

The findings obtained within this theme indicate that teacher candidates perceive the STEAM approach as a structure that arouses curiosity, attracts attention, and encourages affective engagement in the learning process. The metaphors produced reflect the perception that STEAM provides a learning environment that captures individuals’ interest, enhances the desire to explore, and supports motivation toward learning. In this context, the metaphors circus and illusionist point to the surprising, attention-grabbing, and curiosity-provoking aspects of the STEAM approach, whereas the metaphor sky represents exploration, orientation toward the unknown, and limitless learning opportunities. The metaphor deep-rooted product reflects the perception that STEAM fosters a lasting interest and desire for learning in students, creating an influence that deepens over time. A few examples of the metaphors produced are presented below.

*“STEAM education is like a deep-rooted product in the soil, because it contains each root within itself and spreads across broad areas” (KGÖA17).*

*“STEAM education is like the sky to me, because it is vast and boundless” (EGÖA1).*

*“STEAM education is like an illusionist to me, because it works meticulously at the beginning and, in the end, surprises you and gives you enjoyment” (KGÖA14).*

### Discussion and Conclusions

The research findings indicate that pre-service visual arts teachers perceive the STEAM approach not as a simple sum of disciplines, but as a holistic structure composed of complementary fields that enrich and complete one another. This finding is consistent with Yakman’s (2008) theoretical perspective, which conceptualizes STEAM as a model in which science and technology are integrated through art and engineering. A review of similar studies in the literature shows that pre-service science and classroom teachers also frequently conceptualize the integration process within the STEM framework (Ergün & Kızılcı, 2019; Zengin & Uğraş, 2019). However, the fact that pre-service visual arts teachers perceive this interaction as a complementary and holistic structure may be interpreted as a tendency associated with the aesthetic sense of wholeness fostered by art education, as well as with the compositional skills developed through artistic practice.

It was concluded that prospective visual arts teachers perceive the STEAM approach not merely as a product-oriented structure, but as a process-oriented and constructivist form of learning. The metaphors developed “journey,” “path,” and “puzzle” indicate that learning is a gradual and holistic process. This finding is consistent with similar studies in the literature (Başaran & Vural, 2025; Ergün & Kızılcı, 2019). Based on the metaphors expressed by the prospective teachers, it was concluded that the STEAM approach is associated with generating new ideas and engaging in creative design processes. The metaphors developed “creativity,” “dreams,” “invention,” and “lightning” point to the nature of STEAM as an approach that activates individuals’ imagination

and enables innovative ideas to emerge suddenly, in the form of spontaneous insights. Based on this, it is considered that prospective teachers tend to approach the future teaching–learning process within a framework that supports creativity and provides space for experimentation and exploration.

Prospective teachers do not view the STEAM approach as being limited to merely bringing together the disciplines that constitute STEM; rather, they describe it as an approach that incorporates creativity and the aesthetic dimension into the process and addresses these domains in an integrated manner. This finding directly aligns with the literature, which emphasizes the role of art in the STEAM approach as transforming knowledge into an aesthetic and engaging form (Hong et al., 2020; Mou, 2023; Sanz-Camarero, Ortiz-Revilla, & Greca, 2023). Indeed, Mou (2023) reported that students used their artistic skills to visualize scientific content and transform it into more accessible forms, and that this process enabled students to develop an identity as designers.

Prospective teachers view STEAM as an approach that facilitates learning and supports scientific thinking. Metaphors such as “book” and “library” indicate that the STEAM approach is associated with the process of accessing and organizing knowledge. This result suggests that the findings reported by Ergün and Kızılcı (2019) in their study with prospective science teachers parallel the cognitive schemas of prospective visual arts teachers. The “scientific literacy” metaphor indicates that STEAM is perceived as an approach that supports scientific thinking. Piila et al. (2021) emphasize that inquiry and reasoning skills support students in developing meaningful learning rather than relying on rote memorization. Prospective visual arts teachers’ association of this process with scientific understanding aligns with perspectives arguing that the role of art within STEAM is to make scientific knowledge more comprehensible and meaningful.

It was concluded that prospective teachers perceive STEAM practices as engaging structures that arouse curiosity and capture attention. In particular, the metaphors “circus” and “illusionist” developed by the participants highlight the surprising and attention-grabbing

aspects of STEAM practices. Research indicates that STEAM applications offer students a more engaging and innovative learning experience compared to traditional STEM practices (Kashaka, 2024; Jesionkowska, Wild, & Deval, 2020). Such learning environments have been reported to enhance students' levels of classroom participation and foster more positive attitudes toward the course (Jesionkowska, Wild, & Deval, 2020; Wade et al., 2023).

### Recommendations

Since the study was limited to prospective teachers enrolled in the Art Education (Painting–Craft) program of a single public university, the generalizability of the findings is limited. In addition, the study was confined to describing prospective teachers' current perceptions of STEAM. It did not provide longitudinal data on how these perceptions change throughout the teaching–learning process. Within this framework, it is recommended that future researchers conduct studies with broader samples drawn from different universities and encompassing diverse disciplines. In addition, future studies with prospective teachers may incorporate not only linguistic metaphors but also visual metaphors.

### Ethics statement

Throughout the data collection, analysis, and reporting processes, utmost attention was paid to ethical principles regarding human privacy, data security, and confidentiality.

### Data Availability

The data sets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

### Conflict of Interest

None

### REFERENCES

Bassachs, M., Cañabate, D., Nogué, L., Serra, T., Bubnys, R., & Colomer, J. (2020). Fostering critical reflection in primary education through STEAM approaches. *Education Sciences*, 10(12), 384. <https://doi.org/10.3390/educsci10120384>

Başaran, M., & Vural, Ö. F. (2025). Perception of Teachers Towards STEAM and Inquiry-Based Teaching After STEAM Activities Training. *Sage Open*, 15(4), 21582440251388688.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). SAGE. <https://doi.org/10.4135/9781849209687>

Erdoğan, S. (2020). STEAM ve sanat eğitimi ilişkisi [Steam and art education relationship]. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (44), 303–316.

Ergün, A., & Kıyıcı, 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.

Fabian, A. (2025). Metaphor as a cognitive tool in educational research. *Contemporary Educational Research Journal*, 15(2), 148–156.

Filipe, J., Baptista, M., & Conceição, T. (2024). Integrated STEAM education for students' creativity development. *Education Sciences*, 14(6), 676.

Patton, M. Q. (2018). *Nitel araştırma ve değerlendirme yöntemi* (M. But un ve S. B. Demir, Ed. ve C çev.). Pegem Akademi Yayınları

Gülhan, F. (2022). Türkiye'de Yapılmış STEAM/[STEM+ A (Sanat)] Araştırmalarındaki Eğilimlerin Analizi [Analysis of trends in researches on STEAM (STEM + art) made in Turkey]. *Turkish Journal of Educational Studies*, 9(1), 23–46.

Hong, J.-C., Ye, J.-H., Ho, Y.-J., & Ho, H.-Y. (2020). Developing an inquiry and hands-on teaching model to guide STEAM lesson planning for kindergarten children. *Journal of Baltic Science Education*, 19(6), 908–922. <https://doi.org/10.33225/jbse/20.19.908>

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education—A case study. *Education Sciences*, 10(8), 198. <https://doi.org/10.3390/educsci10080198>

Kashaka, N. D. (2024). Arts integration in stem education: A path to steam. *Eurasian Experiment Journal of Humanities and Social Sciences*, 5(3), 49–52.

Piila, E., Salmi, H., & Thuneberg, H. (2021). Steam-learning to mars: Students' ideas of space research. *Education Sciences*, 11(3), 122. <https://doi.org/10.3390/educsci11030122>

Lakoff, G. & Johnson, M.. (1980). *Metaphor we live by*. University of Chicago Press.

López, P., Rodrigues-Silva, J., & Alsina, Á. (2021). Brazilian and Spanish mathematics teachers' predispositions towards

- gamification in STEAM education. *Education Sciences*, 11(10), 618.
- Montés, N., Zapatera, A., Ruiz, F., Zuccato, L., Rainero, S., Zanetti, A., ... & Marathefti, M. (2023). A novel methodology to develop STEAM projects according to national curricula. *Education Sciences*, 13(2), 169.
- Mou, T.-Y. (2023). University students' attitudes towards STEAM via a thematic 3D design project. *Journal of Baltic Science Education*, 22(2), 294–308. <https://doi.org/10.33225/jbse/23.22.294>
- Quigley, C. F., & Herro, D. (2016). "Finding the joy in the unknown": Implementation of STEAM teaching practices in middle school science and math classrooms. *Journal of Science Education and Technology*, 25(3), 410-426.
- Sanz-Camarero, R., Ortiz-Revilla, J., & Greca, I. M. (2023). The impact of integrated STEAM education on arts education: A systematic review. *Education Sciences*, 13(2), 143. <https://doi.org/10.3390/educsci1302014>
- Silva-Hormazábal, M., & Alsina, Á. (2023). Exploring the impact of integrated STEAM education in early childhood and primary education teachers. *Education Sciences*, 13(8), 842.
- Smolin, L., & Preston, E. A. (2025). Centering Art Practices: A Narrative Inquiry Into Elementary Teachers' STEAM Integration. *International Journal of Education & the Arts*, 26(17).
- Spyropoulou, N., & Kameas, A. (2023). Augmenting the impact of STEAM education by developing a competence framework for STEAM educators for effective teaching and learning. *Education Sciences*, 14(1), 25.
- Van Manen, M. (2016). *Writing in the dark: Phenomenological studies in interpretive inquiry*. Routledge. <https://doi.org/10.4324/9781315415574>
- Wade, C. B., Koc, M., Searcy, A., Coogle, C., & Walter, H. (2023). STEAM activities in the inclusive classroom: Intentional planning and practice. *Education Sciences*, 13(11), 1161. [doi.org/10.3390/educsci13111161](https://doi.org/10.3390/educsci13111161)
- Yakman, G. (2008). *STEAM education: An overview of creating a model of integrative education*. Purdue University Proceedings.
- Zengin, M., & Uğraş, M. (2019). Sınıf öğretmen adaylarının STEM eğitimine ilişkin metaforik algılarının belirlenmesi [Determination of class teacher candidates' metaphorical perceptions of STEAM education]. *EKEV Akademi Dergisi*, (77), 57-76.
- Zheng, H.-B., & Song, W.-J. (2010). Metaphor analysis in the educational discourse: A critical review. *US-China Foreign Language*, 8(9), 42–49.