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Examination of Engineering Design-Based Science Education Studies (2012-2024)

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ABSTRACT

In recent years, the number of scientific publications on Engineering Design-Based Science Education (EDBSE) in Turkey has been increasing exponentially. This situation creates the need to review the trend and current status of research in the field. This research aims to examine the EDBSE studies conducted in Turkey in the 13 years since the inclusion of EDBSE studies in the curriculum and to determine the current status and trend with a general framework. Descriptive content analysis, one of the systematic review methods, was used in the research. The keywords "Mühendislik Tasarım" in Turkish and "Engineering Design" in English from TR Index, ERIC and EBSCOhost databases were used to access the studies. 78 articles were included in the research. In the research, it is reached that EDBSE studies were emphasized after 2017, and studies were carried out the most in 2022; the most purposes include the development of skills, examination of opinions, activity development, and academic achievement; qualitative method and documents were used the most; the majority of the participants consisted of secondary school students; the studies were mostly carried out on the subject area of Physical Events. The results of the research showed that EDBSE developed 21st-century skills/competencies, design skills, critical thinking, decision-making, entrepreneurship, problem-solving, creativity, and scientific process skills. The participants expressed positive opinions by stating that EDBSE was fun and motivating, they used interdisciplinary knowledge in the process, they understood the subject more easily, their cognitive and psychomotor skills improved and they wanted to use EDBSE in future lessons. In addition, it was concluded that EDBSE has positive effects on STEM, academic achievement, knowledge acquisition, orientation, and perception and that many activity development studies have been conducted for EDBSE. Finally, the results of the research include that the participants had difficulty in the process, had negative opinions, had misconceptions about EDBSE and STEM, and that teachers and teacher candidates had problems in developing activities.

Mühendislik Tasarım Temelli Fen Eğitimi Çalışmalarının İncelenmesi

Makale Bilgisi

Makale Geçmişi

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ÖZET

Son yıllarda Türkiye'de Mühendislik Tasarım Temelli Fen Eğitimi (MTTFE) üzerine yapılan bilimsel yayınların sayısı katlanarak artmaktadır. Bu durum, alandaki araştırmaların eğilimini ve mevcut durumunu gözden geçirme ihtiyacını doğurmaktadır. Bu araştırma, MTTFE çalışmalarının müfredata dahil edilmesinden bu yana geçen 13 yılda Türkiye'de yürütülen ulusal ve uluslararası dergilerde yayınlanan MTTFE çalışmalarını incelemeyi ve genel bir çerçeve ile mevcut durumu ortaya koymayı ve eğilimi belirlemeyi amaçlamaktadır. Araştırmada sistematik derleme yöntemlerinden betimsel içerik analizi kullanılmıştır. Çalışmalara ulaşmak için TR Dizin, ERIC ve EBSCOhost veri tabanlarından Türkçe "Mühendislik Tasarım" ve İngilizce "Engineering Design" anahtar kelimeleri kullanılmıştır. Araştırmaya 78 makale dahil edilmiştir. Araştırmada veriler yayın yılı, amaç, yöntem, veri toplama aracı, araştırma grubu, konu alanı ve sonuç olmak üzere 7 başlık altında incelenmiştir. Araştırmada MTTFE çalışmalarına 2017 yılından sonra ağırlık verildiği ve çalışmaların en fazla 2022 yılında gerçekleştirildiği; en fazla becerilerin geliştirilmesi, görüşlerin incelenmesi, etkinlik geliştirme ve akademik başarı gibi amaçların yer aldığı; en çok nitel yöntem ve dokümanların kullanıldığı; katılımcıların çoğunluğunu ortaokul öğrencilerinin oluşturduğu ve çalışmaların çoğunlukla Fiziksel Olaylar konu alanı üzerine yapıldığı görülmüştür. Araştırmanın sonuçları MTTFE'nin 21. yüzyıl becerilerini/yeterliklerini, tasarım becerilerini, eleştirel düşünme, karar verme, girişimcilik, problem çözme, yaratıcılık ve bilimsel süreç becerilerini geliştirdiğini göstermiştir. Katılımcılar MTTFE'nin eğlenceli ve motive edici olduğunu, süreçte disiplinler arası bilgiyi kullandıklarını, konuyu daha kolay anladıklarını, bilişsel ve psiko-motor becerilerinin geliştiğini ve gelecekteki derslerde MTTFE'yi kullanmak istediklerini ifade ederek olumlu görüşlerde bulunmuştur. Ayrıca MTTFE'nin STEM, akademik başarı, bilgi edinme, yönelim ve algı üzerinde olumlu etkilerinin olduğu ve MTTFE'ye yönelik birçok etkinlik geliştirme çalışmasının yapıldığı sonuçlarına varılmıştır. Son olarak, katılımcıların süreçte zorlandığı, olumsuz görüşlere sahip olduğu, MTTFE ve STEM konusunda kavram yanılgılarının olduğu ve öğretmenlerin ve öğretmen adaylarının etkinlik geliştirmede sorunlar yaşadığı araştırmanın sonuçları arasındadır.

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INTRODUCTION

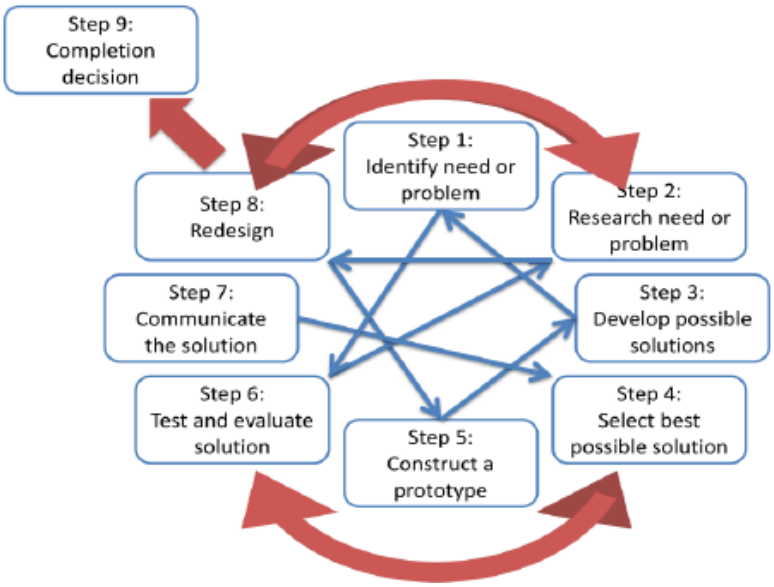
In response to the demands of the contemporary workforce and society, studies have been conducted since the early 2000s to promote an interdisciplinary approach in the field of education (NAE & NRC, 2009). As a result of these studies, it is known that most countries have adopted STEM education (Bybee, 2010). STEM education ensures the development of countries (Aydeniz, 2017) by raising individuals who are successful in solving complex world problems, and therefore researchers all over the world attach importance to STEM and research.

STEM is an interdisciplinary educational approach that emphasizes a holistic understanding of subjects, combining various disciplines (Daugherty, 2013; Erdogan, Ciftci, Yıldırım & Topcu, 2017). According to Sanders (2009), the use of two or more disciplines is sufficient, while according to Bybee (2013), the integration of four disciplines is necessary. Although there is a wide range of definitions and approaches to STEM that are not yet clear (Bybee, 2013), it is emphasized that the application must have six key elements. Although there are various definitions and approaches to STEM, the meaning of which is not clear yet (Bybee, 2013), it is emphasized that its application should have six main elements. These; (i) create a meaningful, engaging, and motivating context to enable active learning of students, (ii) include the engineering design process (EDP), (iii) allow redesign and enable learning from failure, (iv) specifically include math and/or science learning outcomes and other disciplines, (v) student-centered teaching, and (vi) emphasis on group work and communication (Moore, Stohlmann, Wang, Tank, Glancy, & Roehrig, 2014). With STEM education with these elements, deeper conceptual learning, better development of skills and more academic success are provided (Moore, Johnson, Peters-Burton, & Guzey, 2015).

In the literature for STEM education is recommended to use different approaches and methods such as design-based (Becker & Park, 2011), project-based (Tseng, Chang, Lou, & Chen, 2013), problem-based (Ergün & Külekci, 2019), and inquiry-based learning (Keçeci, Alan, & Zengin, 2017). When examining studies conducted in Turkey, it is evident that the Design-Based Approach is predominantly adopted for STEM education (Aydın Günbatar & Tabar, 2019). The Design-Based Approach has been suggested especially for integrating engineering into science education and has been expressed as Engineering Design-Based Science Education (EDBSE) (Wendell, 2008). EDBSE means the development of designs with an engineer's problem-solving approach by creating the necessary context for learning (Wendell, 2008). In this approach, knowledge and abilities of science and mathematics disciplines are combined with experience and the engineering discipline is revealed. Technological innovations occur as a result of combining these three disciplines (Moore et al., 2014). In other words, it can be said that EDP includes all four disciplines and supports the interdisciplinary approach.

EDP refers to a cycle consisting of many steps. This cycle has been modeled differently by different researchers and institutions (Brunsell, 2012; Hynes, Portsmore, Dare, Milto, Rogers, Hammer & Carberry, 2011; NRC, 2012; Smith & Ragan, 2004; Wendell et al., 2010). Although the models for the EDP differ, each model can be grouped under three basic stages: (i) defining the problem, (ii) developing possible solutions, and (iii) determining which best solve the problem (NGSS, 2013). The engineering design model, which is frequently used and accepted in the literature, is shown in figure 1.

Figure 1
Engineering Design Model (Hynes Et Al., 2011)



According to Hynes et al., (2011), the EDP begins with the *Identify and Define Problems stage*. At this stage, open-ended engineering problems with many reasonable solutions in a real-world context are presented. Students are told to find the problem from the given scenario at this stage. There should be many realistic solutions for the given scenario. *In the Research the Problem stage,* students are expected to conduct research for the problem, and accept that there are many variables when solving the problem. *In the Develop Possible Solution(s) stage*, more than one solution is recorded, planned, and group work is carried out. At this stage, students should actively brainstorm in groups so that they can learn individually and increase their creativity. *In the Select the Best Possible Solution(s) stage,* students use their knowledge of mathematics and science to choose the best solution and constantly evaluate the process. Ultimately, it is expected that the best possible solution will be chosen for the individual or group design. *In the Construct a Prototype stage,* students are asked to develop prototypes that will be tested to reach the final product. *In the Testing and Evaluation of Solutions stage,* students decide whether their prototypes are successful. If necessary, they rearrange the prototype and this way they learn from their failures. *In the Communicate the Solution(s) stage,* all students are expected to present their results with their teammates and teachers and discuss the reasons for unsuccessful designs. *In the Redesign stage,* students evaluate the process and develop their prototypes. *In the Completion stage,* it is decided whether a final product has been obtained. In summary, an engineering problem with certain criteria and limitations is best solved through design development (NRC, 2012).

The EDP is increasingly used at the K-12 level and contains many documents on the importance of integration into educational environments (MoNE, 2013, 2017, 2018; NGSS, 2013). The learning outcomes of the activities (8.5.3.1.Designs a project for the efficient use of resources.) that can be carried out with the application of the EDP are implicitly included in the 2013 Science Curriculum in Turkey (MoNE, 2013). In the 2017 Curriculum, the addition of "Engineering and Design Skills" aims to enable students to utilize interdisciplinary approaches in problem-solving and apply their knowledge to create products for the first time (MoNE, 2017). The 2018 Curriculum, unlike the previous program, aims to carry out engineering design applications during the year with the activities at the end of each unit under the title of "Science, Engineering and Entrepreneurship Applications" and to present the resulting products at the end-of-year science fair (MoNE, 2018). After the inclusion of

engineering applications in the curriculum in Turkey, STEM education started to be carried out with the EDBSE approach and became popular (Aydın Günbatar & Tabar, 2019).

Winardo, Rusdiana, Samsudin, Susilowati, Jahan Ahmad, and Ayu Afifah (2020) examined the quantitative experimental EDBSE studies using a systematic literature review method and focused on the subject area of the EDBSE studies and what their benefits are. In the research, it was concluded that EDBSE was mostly carried out in the field of science and physics and that EDBSE had attitudinal benefits, cognitive benefits, procedural benefits, and a combination of these three. In another research, Arık and Topçu (2020) examined the functioning of the EDP in EDBSE studies with the meta-synthesis method. In the research in which only qualitative studies were included, it was concluded that EDP was mostly started by using problem scenarios and open-ended questions, and different teaching methods such as laboratory, brainstorming, and writing activities were used in the process. Özünlü and Çepni (2023) conducted a study to determine the trend of engineering design-based science teaching in Turkey by analyzing 40 studies (21 articles, 19 theses) conducted between 2013-2022 with the thematic analysis method.

In recent years, the number of scientific publications on EDBSE in Turkey has been increasing exponentially every year. There is a need to review the situation and trends in research in this field. It aims to examine the EDBSE studies published in national and international journals carried out in Turkey in the last 13 years since the inclusion of EDBSE studies into the curriculum and to determine the current trend by revealing the current situation with a general framework. In this research, unlike previous studies, both national and international journal articles conducted with all research methods were examined, and the number of studies examined was quite large (78 articles) and kept up to date. In this way, it is aimed to achieve more comprehensive results. It is thought that the research will assist researchers determine future research priorities. The problem status is "What is the orientation of the studies carried out in EDBSE in Turkey?". The sub-problems are as follows:

EDBSE studies carried out in Turkey;

- How is the distribution in the last 10 years?
- How is the distribution according to the purposes?
- How is the distribution according to the research method?
- How is the distribution according to the study group?
- How is the distribution according to the data collection tools?
- How is the distribution according to the subject area?
- How is the distribution according to the results?

METHOD

Research Model

In the study, descriptive content analysis (DCA) was employed to investigate research on EDBSE in Turkey from 2012 to 2024 (Çalık & Sözbilir, 2014). DCA is a systematic review method that seeks to uncover the overarching patterns and themes within studies focusing on the same subject or content (Jayarajah, Saat & Rauf, 2014; Suri & Clarke, 2009; Umdu Topsakal, Çalık & Sergeant, 2012). To identify general trends in DCA, qualitative and quantitative studies can be analyzed separately from each other (Selçuk, Palancı, Kandemir, & Dündar, 2014).

Data Collection

To be included in the research, EDBSE studies conducted in Turkey were accessed from TR Index, ERIC, and EBSCOhost databases, using both Turkish "Mühendislik Tasarım" and English

"Engineering Design" keywords. Various criteria were considered for the inclusion of the reached studies in the research. These are (1) being carried out by Turkish researchers in Turkey, (2) being aimed at science education, (3) being article, (4) focusing on engineering design-based education, and (5) being carried out between 2012 and April 2024. Finally, a total of 78 articles published in national and international journals were included (appendix 1).

Data Analysis

The data obtained in the research were analyzed by content analysis. In the process, firstly, the full texts of the articles were reached. Then, the data were examined under seven headings: publication year, purposes, method, subject area, study group, data collection tools, and conclusion. To analyze the data based on the consensus of the researchers, five randomly selected articles were initially analyzed independently and the results were compared. After analyzing the articles based on consensus, all data were coded in Microsoft Excel. Then, categories were created with codes related to the same title or subject. As a result, themes were created by bringing together similar categories. Then, the data were re-coded by two faculty members who are experts in the field. Miles and Huberman's (1994) formula "reliability=(number of consensus)/(total agreement+number of disagreement)" was used to calculate coding reliability. Coding reliability was calculated as 0.97. With the result obtained, it can be said that a perfect fit is achieved (Miles & Huberman, 1994).

Ensuring Credibility and Confirmability

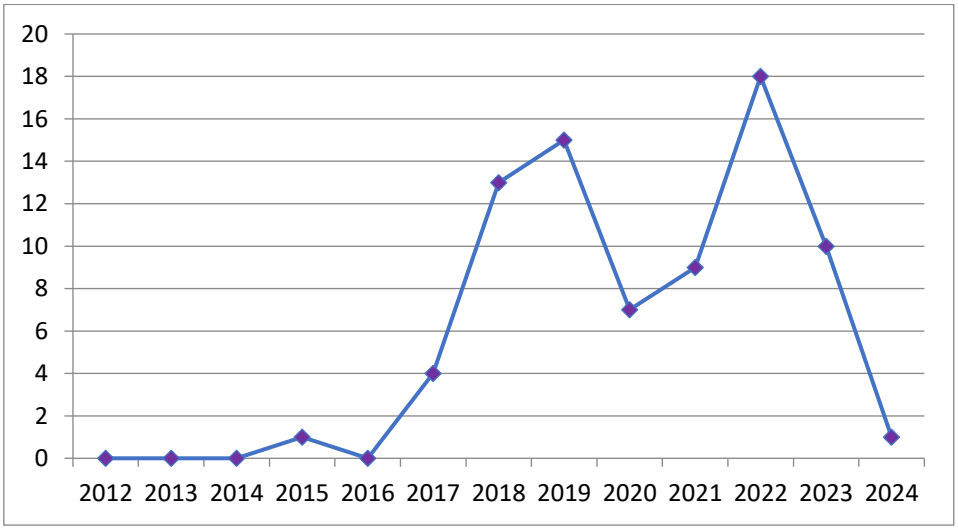
In this research, which was carried out with DCA, strategies such as expert examination, detailed description, the position of the researcher or reflectivity, revealing the limits of the research, repeatability (Merriam, 2013) and coding reliability were used to ensure credibility and confirmability (Miles & Huberman, 1994).

FINDINGS

In the research, 78 articles on EDBSE conducted in Turkey were examined. Findings related to each research question are presented in tables or graphs and are given below in order. Data for the first sub-problem are presented in Figure 2.

Figure 2

Data on The Distribution of The Studies Examined By Years



As seen in Figure 2, studies were realized zero (0.00%) in 2012, zero (0.00%) in 2013, zero

(0.00%) in 2014, one (1.28%) in 2015, zero (0.00%) in 2016, four (5.12%) in 2017, thirteen (16.66%) in 2018, fifteen (19.23%) in 2019, seven (8.97%) in 2020, nine (11.53%) in 2021, eighteen (23.07%) in 2022, ten (12.82%) in 2023, and one (1.28%) in 2024. In summary, it is seen that EDBSE studies were emphasized after 2017, and studies have been carried out in 2022 the most in the last thirteen years. Data for the second sub-problem are presented in Table 1.

Table 1

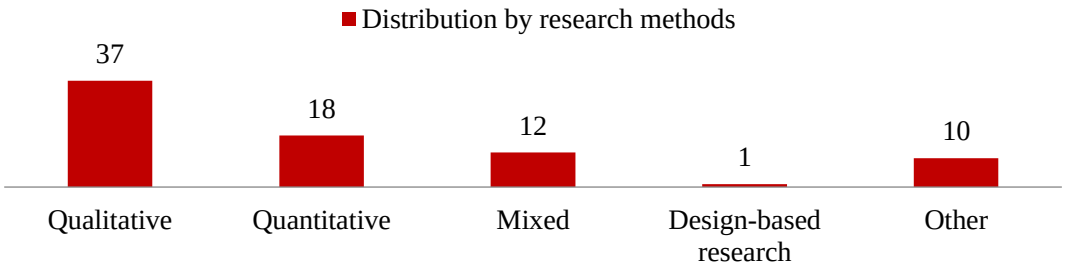
Data on the Distribution of Purposes in the Studies Examined

Theme	Category	Code	f	%
Engineering Design Domain	Engineering Design Process	Opinions	30	26.08
		Activity development	17	14.78
		Textbook review	3	2.60
Cognitive Domain	Knowledge	Academic achievement/Content knowledge	4	3.47
		Engineering	3	2.60
		Conceptual understanding	1	0.86
		Technology	1	0.86
		Engineer	1	0.86
	Skill	Student performance/design skill	7	6.08
		21st century skills/competencies	6	5.21
		Problem solving	3	2.60
		Creativity	3	2.60
		Decision making	2	1.73
		Entrepreneurship	2	1.73
		Critical thinking	1	0.86
		Science process	1	0.86
Affective Domain	Perception	Engineering perception	5	4.34
		Engineer perception	3	2.60
		Perception of engineering education	1	0.86
		Technology perception	1	0.86
		Career perception	1	0.86
		Inquiry learning perception	1	0.86
	Orientation	Career interest	2	1.73
		Teaching intention	1	0.86
		Engineering attitude	1	0.86
		Environmental attitude	1	0.86
	Motivation	Learning motivation	1	0.86
STEM Domain	STEM	Attitude	4	3.47
		Content knowledge	2	1.73
		Awareness	2	1.73
		Perception	1	0.86
		Teaching orientation	1	0.86
		Perception of competence	1	0.86
		Career interests	1	0.86

As seen in Table 1, most of the studies examined focused on the Opinions (26.08%) purpose. Opinions of different types of participants such as students, teacher candidates, teachers and parents were taken in the studies. Other purposes that are heavily emphasized are Activity Development (14.78%), Student Performance/Design Skill (6.08%) and 21st Century Skills/Competencies (5.21%).

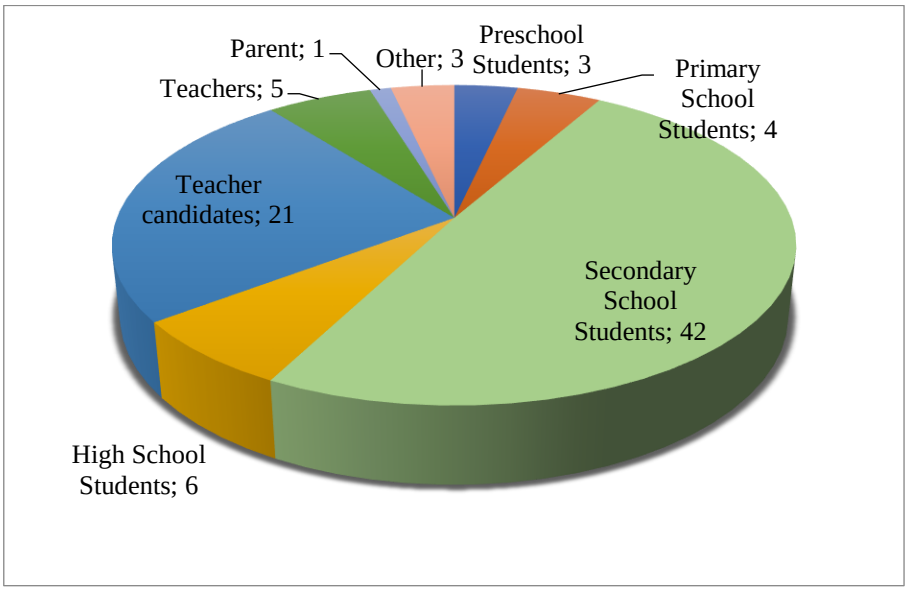
Data for the third sub-problem are presented in Figure 3.

Figure 3
Data on the Distribution of the Methods of the Studies Examined



As seen in Figure 3, studies were conducted thirty-seven with qualitative (47.43%), eighteen with quantitative (23.07%), twelve with mixed (15.38%), ten with other (12.82%), and one with design-based research (1.28%) research methods. In summary, the majority of EDBSE studies have been conducted using the Qualitative research method. The methods of the studies aiming at developing and promoting activities are included under the title of other research methods. Data for the fourth sub-problem are presented in Figure 4.

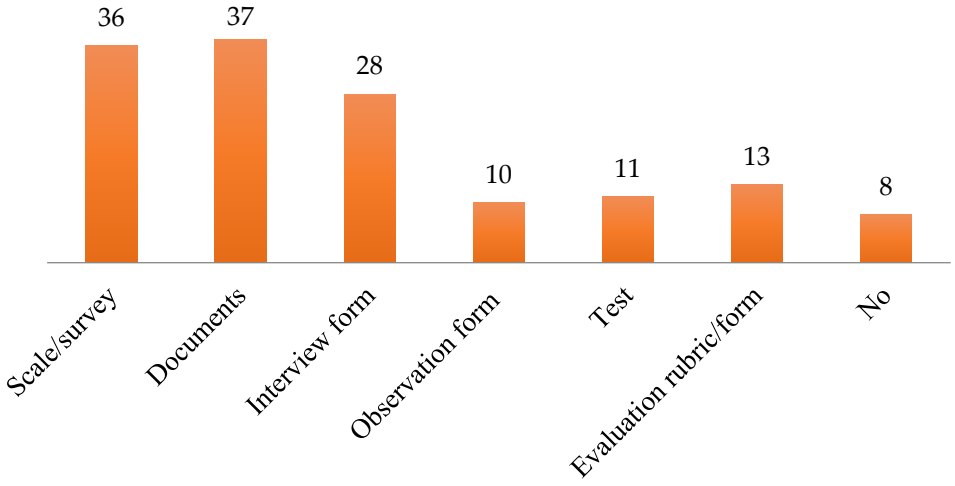
Figure 4
Data on the Distribution of Study Groups of the Examined Studies



As seen in Figure 4, studies were conducted forty with secondary school students (49.0%), twenty with teachers candidates (25.0%), six with high school students (7.0%), five with teachers (6.0%), four with primary school students (5.0%), three with preschool students (4.0%), one with parents (1.0%), and three with others (4.0%). The studies carried out with teacher candidates are for the branches of Science (n=9), Preschool (n=6), Primary (n=3), Chemistry (n=2), and Classroom teacher candidates (n=1). The studies carried out with teachers are for the branches of Science (n=4), and Primary (n=1). Some studies were conducted with more than one and different study groups. The course book review study was included under the other title. Data for the fifth sub-problem are presented in Figure 5.

Figure 5

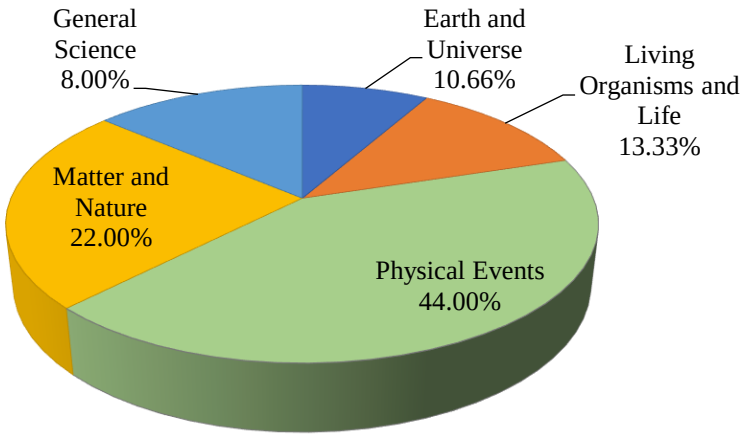
Data on the Distribution of Data Collection Tools Used In the Examined Studies



As seen in Figure 5, studies were used thirty six scales/surveys (25.17%), thirty seven documents (25.87%), twenty eight interview forms (18.88%), ten observation forms (6.99%), eleven tests (7.69%), and thirteen assessment rubrics/forms (9.09%). In the eight studies examined (5.59%), no data collection tools were used. In summary, it is seen that documents are used as data collection tool in the majority of EDBSE studies. As documents in studies, five student drawings, five diaries, five reflection questions, three textbook, five worksheets/experimental sheets, two reports, eight field notes, one video recordings, two photos and one design products were used. In addition, the Tests used in the studies are intended to measure perception, academic achievement, engineering design skills, scientific creativity, problem solving, scientific process skills and decision making skills. Data for the sixth sub-problem are presented in Figure 6.

Figure 6

Data on the Distribution of Subject Areas of the Examined Studies



As seen in Figure 6, studies were conducted forty-six Physical Events (44.00%), twenty-six Matter and its Nature (22.00%), thirteen Living Organisms and Life (13.33%), nine Earth and Universe (10.66%), and fifteen General Sciences (8.00%) in subject areas. In summary, the studies were mostly carried out on the subject areas of Physical Events, and the Earth and the Universe the

least. Studies that do not specify a subject area, do not include EDBSE application and examine the textbook are classified as General Sciences. Data for the seventh sub-problem are presented in Table 2.

Table 2
Data on The Results of the Examined Studies

Theme	Category	Code	f	%
Engineering Design Domain	Engineering Design Process	Participants have positive opinions on EDP	23	17.6
		There are activity development studies for EDP	13	10.4
		Participants experience various difficulties in EDP	12	9.6
		Participants have negative opinions towards EDP	5	4
		EDP steps are not included in the textbook	3	2.4
		Students develop creative products	3	2.4
		Teachers and teacher candidates have difficulties in developing activities for EDP	2	1.6
		Participants made suggestions in their opinions on EDP	2	1.6
		Teacher candidates are successful in developing activities for EDP	1	0.8
		Teacher candidates have misconceptions about EDP	1	0.8
Cognitive Domain	Knowledge	EDP contributes to the acquisition of knowledge (content knowledge, technology, engineer and engineering knowledge)	5	4
		EDP increases academic achievement	3	2.4
		EDP increases conceptual understanding	1	0.8
		EDP removes misconceptions	1	0.8
	Skill	EDP improves skills (21st century skills/competencies, design skills, critical thinking, decision making, entrepreneurship, problem solving, creativity, scientific process)	24	19.2
		Teacher candidates' creativity and decision-making skills are low	1	0.8
Affective Domain	Perception	EDP has positive effects on perception (engineering, engineering, technology, inquiry learning and engineering education)	4	3.2
		Students have misconceptions in their engineering perceptions	1	0.8
	Orientation	EDP contributes positively to participants' orientations (engineering attitude, teaching intention, and career interest)	4	3.2
		EDP has no effect on attitudes towards science, engineering and problem solving	2	1.6
	Motivation	EDP improves learning motivation	1	0.8
STEM Domain	STEM	EDP has positive effects on STEM (interest, motivation, perception, content knowledge, attitude, awareness, teaching orientation, career interests and competence perception)	12	9.6
		Teacher candidates have misconceptions about STEM fields	1	0.8

As seen in Table 2, when the results of the studies examined are seen, skills are developed (19.2%), there are positive opinions about EDP (17.6%), activities that can be applied in/out of the

classroom environments are developed (10.4%), there are positive effects on STEM (9.6%), knowledge is acquisition (4%), and academic achievement is increased (2.4%) and orientation (3.2%) and perception (3.2%) are improved positively. In addition, it is among the results of the studies that participants had difficulties in EDP (9.6%), teachers and teacher candidates had difficulties in developing activities (1.6%), participants had negative opinions (4.0%), and there were misconceptions about EDP (0.8%) and STEM (0.8%).

DISCUSSION & CONCLUSION

In this research, the studies carried out on EDBSE in Turkey were examined comprehensively and holistically, and the general orientation was tried to be explained. In this context, 78 articles were examined. Data were obtained by using the DCA method in line with the research questions.

When the data related to the first sub-problem are examined, it is seen that the number of studies conducted between 2012-2024 increased between 2012-2019, decreased between 2020-2021, and then increased again. Only one study conducted between 2012 and 2016 was found, and it was observed that EDBSE studies were focused on after 2017 and there was a significant increase, especially in 2019. This situation can be explained by the emphasis on Engineering Applications in the 2017 and 2018 Science Curriculum and it takes time for researchers to gain awareness of this issue. Another possible reason may be that the researchers conducted their EDBSE studies using the STEM word. Aydın Günbatar and Tabar (2019) carried out the content analysis of STEM research conducted in Turkey and concluded that the design-based learning approach was used the most under the STEM title. To give a specific example, for example, Çınar, Pırasa, Uzun, and Erenler in their study in 2016 mentioned that science teacher candidates developed engineering design models in the process, but their studies were framed under the STEM title.

The decrease in the number of studies in 2020 and 2021 may have been caused by the interruption of EDBSE applications due to the pandemic. Sarı and Nayır (2020) in their research in which they examined the education reports, stated that there were difficulties in maintaining and developing distance learning in pandemic. Studies in which science teachers' opinions on the process are taken also overlap with the results. It is the result of many studies in which there are difficulties in communicating in the process, teachers feel inadequate, the participation rate is low, and there are concerns about completing laboratory/workshop activities (Bakırcı, Doğdu, & Artun, 2021; Bakioğlu & Çevik, 2020). The reason for the highest number of studies to be carried out in 2022 may be the pandemic. The research that could not be carried out and accumulated in the previous 2 years may appear in 2022 with the end of the pandemic. In 2023 and later, there was a decrease in the number of EDBSE studies that reached quantitative saturation. Carrying out studies that are rich in number and content has contributed to the qualitative development of EDBSE by ensuring understanding and awareness of EDP.

When the data related to the second sub-problem are examined, it is seen that the studies carried out for EDBSE in general; it has been concluded that it includes purposes for Engineering Design, Cognitive, Affective and STEM domains. When the purposes are considered in detail, there are purposes for Opinions, Activity Development, Student Performance/Design Skills, 21st Century-Skills/Competencies, Engineer and Engineering Perception, STEM Content Knowledge and Attitude, respectively. Studies conducted in science education were seen focus on similar purposes (Herdem & Ünal, 2018; Yıldırım & Gelmez-Burakgazi, 2020). Herdem and Ünal (2018) concluded in their research that classroom activities, opinions, perceptions, attitudes, and career awareness purposes are frequently repeated.

When the data related to the third sub-problem are examined, it was concluded that most of the

studies were carried out with the qualitative research method. Afterward, it was seen that quantitative, mixed, and design-based research methods were preferred, respectively. The reason for this situation is related to the selection of the method in research depending on the objectives of the study. It is quite remarkable that the design-based research method was preferred in only one of the 78 studies examined. In this case, it can be said that this method is not preferred much. The reason for this can be interpreted as the design-based research method being a new method and being less known in Turkey. Kula and Sadi (2016) concluded that most of the studies on science education between the years 2005-2014 were carried out with the quantitative method. This result contradicts the findings of our research. EDBSE covers a process that includes certain steps. It can be argued that more emphasis is placed on qualitative studies to comprehend how these steps are perceived and interpreted by students and teachers. Furthermore, the prevalence of qualitative methods in studies may be attributed to laying the groundwork for subsequent quantitative research.

When the data related to the fourth sub-problem are examined, it was concluded that the studies were carried out mostly with secondary school students and then with university-level teacher candidates. Studies with teacher candidates are mostly related to Science, Primary Education, Chemistry, and Preschool branches, respectively. In addition, the least preferred study groups are primary school students, preschool students, high school students, and parents. It can be thought that the reason why the study groups in the examined studies are mostly middle school students and science teacher candidates is since academicians have easy access to science teacher candidates and that trained science teachers can conduct more studies. Similar to our research, it shows that the studies conducted with Science are mostly carried out with secondary school students (Herdem & Ünal, 2018). However, considering that engineering design skills should be acquired and maintained from childhood, secondary school level may be a late age group. Polat and Bardak (2019) state that early childhood should be targeted for all approaches, not just for the EDP, to make the right start to education.

When the data related to the fifth sub-problem are examined, it was concluded that documents and scale/survey were used the most. Afterward, it was concluded that interview forms, evaluation rubric/form, tests, and observation form were used respectively. Considering that the studies in the research were carried out with qualitative research methods, this finding is not surprising. Due to the nature of qualitative studies, documents, interview, and observation forms are used to collect data (Silverman, 2018).

When the data related to the sixth sub-problem are examined, it was concluded that most studies were carried out on the subject area of Physical Events. Subsequently, studies were conducted on the subject areas of Matter and its Nature, Living Organisms and Life, and the Earth and the Universe, in that order. The prevalence of studies in the subject area of Physical Events can be attributed to the predominance of concrete and macro-level concepts within this subject area. So much so that the result of many events (eg, the propagation and reflection of light, shadow events, friction force, gravitational force, transmission of electricity, mirrors, simple machines, and pressure) can be observed and tested with the naked eye. In addition, when the Science Curriculum is examined according to subject areas, it is seen that the subject area with the most learning outcomes (75 learning outcomes) at the 5th-8th grade levels is Physical Events (MoNE, 2018). This may have enabled the studies to be carried out mostly in the field of Physical Events.

At least the studies examined were in the subject area of Earth and Universe. This subject area was moved from the last unit to the first unit with the 2018 science curriculum, and thus, the necessary importance was given to the subject area. However, it is still noteworthy that it is the subject area on which the least research has been conducted. Ayvacı and Sezer (2018) determined that there are few

studies on the subject as a result of the analysis they conducted on the subject area of Earth and Universe, in other words astronomy. The fact that few studies have been conducted on the subject of Earth and the Universe can be explained by the difficulties in testing the developed designs. EDP begins with real-world problems. Products designed to solve problems are tested in a realistic context. It is thought that not all engineering designs for events and concepts related to the Earth and the Universe can be tested in a real context (for example, in a zero-gravity environment). This may have a limiting effect on the conduct of studies in this subject area. In addition, when the Science Curriculum is examined according to subject areas, it is observed that the subject area with the least learning outcomes (25 learning outcomes) at the 5th-8th grade levels is Earth and Universe (MoNE, 2018). This may have caused at least the studies to be carried out in the field of Earth and Universe.

When the data related to the seventh sub-problem are examined, respectively, it was seen that EDP improved skills, participants have positive opinions about EDP, there are activities to develop and introduce activities that can be applied in/out of the classroom for EDP, there are positive effects on STEM, knowledge is gained, orientation and perception have been developed positively. In today's world, students require a multitude of skills to address the challenges they encounter in daily life and contribute to societal development. Our study reveals that EDBSE enables the development of many 21st-century skills, especially design skills. The results of many studies support this situation. For instance, in the research conducted by Özçelik and Akgündüz (2018), it was concluded that students achieved learning outcomes in science and mathematics and developed 21st-century skills thanks to EDP. Putra, Sulaeman, Supeno, and Wahyuni (2021) suggested using EDP so that high school students can demonstrate their critical thinking skills in educational environments and include them in the process. Strong (2013) emphasized in his study with primary school students that EDP can significantly improve mathematics and science process skills. Syukri, Halim, Mohtar, and Soewarno (2018) stated that EDP is a suitable approach to improve high school students' problem-solving skills in physics.

In our study, in 23 of the 30 studies in which opinions were taken, positive opinions were expressed about EDP, while negative opinions were included in only five of them. According to the results obtained, it is a common emphasis that the participants have positive opinions about EDP. In their positive opinions, the participants stated that EDP is fun and motivating, they use interdisciplinary knowledge in the process, they understand the subject more easily, many skills such as cognitive and psycho-motor have improved and they want to use EDBSE in future lessons. The results are similar to the results obtained in the literature (Aydın & Karslı Baydere, 2019; Sarı & Yazıcı, 2019). In their negative opinions, they expressed feeling unwell due to experiencing failure in the process, encountering challenges in group work and material procurement, feeling inadequate, and perceiving the activities as time-consuming. The results are similar to the results obtained in the literature (Harman & Yenikalaycı, 2021; Sungur-Gül, & Marulcu, 2014). In our study, in addition, it is noteworthy that there are many activity development studies for EDBSE and the activities are explained in detail by the researchers. This situation brings to mind that the researchers made attempts to understand EDBSE and aimed to contribute to the teachers and the education system.

Apart from these, it was concluded in this study that the participants had difficulties in EDP, that teachers and teacher candidates had problems in developing classroom activities, that the participants had negative opinions, and that there were misconceptions about EDP and STEM. Similar findings were found in the content analysis research conducted by Ültay and Aydın (2017) on science education. The difficulties experienced by the participants in EDP may be due to their lack of experience in EDBSE (Bozkurt Altan, Üçüncüoğlu, & Özek, 2019) or their weak engineering design skills.

RECOMMENDATIONS

Considering that EDBSE applications have been disrupted after 2019 due to the pandemic, it can be recommended that teachers be prepared for this process and that the development, implementation and effects of EDBSE activities that can be carried out in distance, blended or hybrid learning environments are investigated.

It is recommended to carry out scale development or adaptation studies and to compare the results with the qualitative findings.

Considering the limited number of studies conducted at the preschool, primary, and high school levels, it is advisable to enhance research efforts at these educational tiers.

It is recommended that teachers and teacher candidates follow academic publications that aim to develop and introduce activities to overcome the difficulties in developing activities for EDP.

Projects should be developed to explore what EDBSE entails and how to implement it, accompanied by providing in-service training for teachers.

Collaboration between teachers and engineers can be made so that EDBSE, where engineering and science are intertwined, can be understood and participants can overcome the difficulties.

In the examined studies, the subject area of Physical Events was preferred the most. In this case, it may be recommended to develop, implement and examine the effects of activities for different subject areas.

Since design-based research method is used in very few studies, it is recommended to carry out researches with this method.

In the Skill-Based Science Course Curriculum (Maarif Model) renewed in 2024, learning outcomes that integrate science, technology, engineering, and design skills and examples of activities such as “Making Taka” (p.140) for the first time for the use of EDP were included (MoNE, 2024). Considering the results of this research and the objectives of the curriculum, it is recommended that EDBSE research be continued in line with the renewed goals. For example, the relationship between social-emotional learning skills mentioned for the first time in the 2024 Science Course Curriculum and EDP can be examined. The performances of students with low and high social-emotional learning skills in EDP can be compared or the effect of EDP on social-emotional learning skills can be investigated.

It has been noticed that although EDBSE is included in the content of some STEM research, this concept is not present or is not emphasized enough. Although the term STEM is popular, it represents a wide range that includes many methods and approaches. It is recommended that studies working on EDBSE use at least one of the expressions "Engineering Design-Based Science Education" and "Engineering Design Process" in their titles, keywords and/or abstracts in order to better conceptualize their research.

Ethical Approval

It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.

Conflict of Interest

There is no conflict of interest with any organization or individual relevant to the study, stated the authors.

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