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Research Trends and Features of Robotics Studies in Educational Technology and STEM Education: Data Mining on ERIC Sample

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Abstract. In this study, publications in ERIC about Robotics, Educational Technology in Robotics (ET-in-Robotics), and STEM in Robotics (STEM-in-Robotics) have been reached through data mining. The reached studies were analyzed in terms of their release year, titles, abstracts, and ERIC descriptions. In this process, it aimed to put forward its research trends and features. The analysis of the 1339 publications that were published between 01/01/1973 and 31/12/2021 and available in ERIC has been made by using several Python libraries. These analyses are presented in the form of tables and word clouds. The results showed that the number of publications available in ERIC was the highest between 2017 and 2021. Also, in the last five years, the number of publications available on Robotics in ERIC has gradually increased. In addition, the words "learning", "robotics", and "technology" are important for all three topics whereas the words “child”, "science", “programming” and "teacher" for ET-in-Robotics, and the words "school" and "engineering" for STEM-in-Robotics come to the fore. Moreover, the most frequently assigned descriptor by ERIC staff to these publications has been found to be "teaching methods". When evaluated in general, in the STEM-in-Robotics field, more specific topics were focused, and robotic activities are taken as a type of instructional technology while in the ET-in-Robotics field robotic activities were taken as a type of educational technology. As a result, a publication that will serve as a guide for new research in the field of robotics has been presented.

Keywords: Robotics, Educational Technology, STEM, Big Data, Data Mining.

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1. INTRODUCTION

By the 21st century, the rapid increase in the human population led to many problems with the development of societies. Research to find solutions to problems has given great impetus to the development of science and technology. Technology has been progressing day by day. Thus, every new generation added to the previous one and contributed to the acceleration of this situation. This situation is effective in the development of situations such as research, curiosity, criticism, questioning, and high-level thinking in societies. Also, it enabled societies to integrate these concepts into the education processes very quickly. In this sense, the questioning and investigative thinking transmitted to individuals by researchers and educators during the education process enabled individuals to adapt to the changing world faster. Therefore, educational technologies gained great importance in order to keep pace with the developing technological world and not to be behind the age.

In the last century, the use of educational technologies has come to the forefront in the context of constructivist education, which aims to enable students to gain higher-level mental skills such as problem-solving, analysis, and synthesis. Along with many educational technologies, robotics, which are popularly developed and taught by students and provide easy application possibilities, have been used frequently in education. Scientists are also investigating the effectiveness of robotics, which is being used in educational processes and rapidly increasing the use, of STEM (Science, Technology, Engineering, and Math) (Sullivan & Bers, 2016).

Education is a field that is closely related to society. It is significantly affected by developing technology as a discipline on which new studies are carried out continuously. With the development of technology, the subject of innovative educational technologies has become the focus of researchers to increase the efficiency of students in educational activities. One of the innovative educational technology applications is Robotics in Educational Technologies. Robotic technologies have started to be used in daily life besides being used in the laboratory environment. Robotic technologies are used in many fields such as medicine, military, and engineering (Yolcu & Demirer, 2017). With the use of robotics in educational technologies, Robotics is used as a teaching tool for different disciplines and courses such as STEM, programming, mechanical, electrical, and electronic (Cam & Kiyici, 2022; Foss, Wilcoxen & Rasmus, 2019; Hangün, 2019; Şimşek, 2019). The use of robotics in educational technologies, whose basic theories are constructivism and constructionism (Papert, 1993; Siper-Kabadayı, 2019), has main objectives. These objectives are, to support teaching subjects such as artificial intelligence, design, engineering applications, robot production, and programming; to develop broad learning skills such as engineering design, inquiry, product-oriented thinking, analytical thinking, creative thinking, teamwork, research and more willingness to explore; to gain and develop STEM knowledge and skills at an early age; increasing individuals' willingness to participate in science, mathematics, education and technology, and reducing psychological or cultural barriers to engaging in these fields

(Barak & Assal, 2018; Bers, Flannery, Kazakoff & Sullivan, 2014; Chaudhary, Agrawal, Sureka & Sureka, 2016; Ching et al., 2019; Yolcu & Demirer, 2017).

Robotics is a powerful and flexible teaching tool where students carry out robot programming activities using special programming tools (Alimisis, 2013). The use of robotic activities in education aims to develop high-level thinking skills in schools such as creativity, critical, and analytical thinking. It also creates engineering process logic and provides learners with learning about sensors, motors, programming, and the digital field (Bers, 2010; Eguchi, 2010; Mikropoulos & Bellou, 2013). Robots have a flexible structure that allows trainers to propose different models for a wider range of training (Spolaôr & Benitti, 2017). A useful learning environment can emerge when the features of robots, such as the ability to perform repetitive tasks, flexibility, the ability to present digital data, interactivity, and the option to present a humanoid view, including the body, match the teaching objectives (Chang, Lee, Chao, Wang & Chen, 2010). Robotics in education often provides students with fun activities and hands-on experiences that help create an engaging, eye-catching, and interactive learning environment (Alimisis, 2013).

Robotics has been having an important place in education in the world for more than 20 years (Ospennikova, Ershov & Iljin, 2015). Today, with the increasing interest in STEM education, robotics is an excellent learning tool in learning STEM fields through hands-on activity and it is seen as an innovative solution in this field (Rockland et al., 2010; Zeidler, 2016). True STEM education is an education that enables individuals to understand how tools, equipment, and mechanisms work and it increases the use of technology by individuals (Bybee, 2010). Robotic applications also play an important role in STEM education with this common feature.

Robotics is considered a useful teaching technology that supports the development of 21st-century learning skills, as well as improving students' learning performance. Robotics is mostly used in STEM education as a team-based design project where students are usually allowed to communicate and collaborate (Barker & Ansorge, 2007; Beynon, 2016). Task-based and project-oriented course designs in robotics education enable students to develop problem-solving skills and become active learners (Nourbakhsh et al., 2005). It is seen as an interdisciplinary activity used in the fields of Robotics, Science, Technology, Engineering, Mathematics, and Informatics. Thus, it provides innovative and great benefits to education at all levels (Alimisis & Kynigos, 2009; Kazakoff, Sullivan & Bers, 2013). With the increase in STEM-supported programs day by day, students' interest in STEM fields increases through applied robotics (Brand, Collver & Kasarda, 2008; Ivey & Quam 2009; Caron 2010). Robotics encourages students' work within the collaboration, not only by providing them with information on STEM concepts but also on the interdisciplinary nature of STEM (Yuen et al., 2014).

While explaining the connection of robotics with STEM, there are two different perspectives in studies on this subject. The first of these sees robotics education as a sub-discipline of STEM education. On the other hand, the second one considers robotics education as a separate discipline that shares many common teaching contents with

STEM education but has different teaching content and characteristics (Jung & Won, 2018). Robotics should not be seen only as a computer science discipline, but also benefits from fields such as science, technology, engineering, and mathematics. Countries that argue interdisciplinary education is important to carry out robotics education within the scope of STEM. Robotics in STEM is used in many countries (Konyaoğlu, 2019). In this regard, robotics in STEM can be defined as an interdisciplinary STEM application that includes engineering design and programming together (Sullivan, 2017). Students studying Robotics in STEM manage to create an environment where they can explore, build, program, and have fun while playing (Eraytaç, 2019).

Robotics applications are becoming more and more widespread all over the world as it brings many educational benefits. In the 2017 report, which reveals the current trends in educational technologies published annually by the New Media Consortium, it was stated that robotics technologies will have more place in educational environments since 2017 (Becker et al., 2017). Considering that the interest of children in the fields of STEM can be established starting from preschool and primary school years, the importance of studies on robotics in the fields of educational technology and STEM becomes apparent. Therefore, in the research, publications in ERIC on Robotics, Educational Technology in Robotics (ET-in-Robotics), and STEM in Robotics (STEM-in-Robotics) have been reached through data mining. Thus, their release year, titles, abstracts, and ERIC descriptions have been analyzed, and it aimed to put forward their research trends and features.

2. METHOD

Research Process

The current study aimed to determine the trends of the studies by examining the studies belonging to the "Robotics", "ET-in-Robotics" and "STEM-in-Robotics" descriptors in the ERIC database. Thus, big data was studied, and the data mining method was used in the study.

The whole process of collecting large amounts of data, storing it by storing, analyzing it, and making necessary predictions with the results obtained can be defined as big data (Feinleib, 2013). It is the most effective approach to use visualization to present the information obtained from big data clearly and comprehensively and to convey the desired messages. Infographics, which have statistical techniques, software, and graphing information in the background, have become highly functional tools for analysts and users today. Big data and big data analysis can be considered as meta-approach that employ data analysis approaches from different disciplines and tries to make sense of data. The reason why big data collection analysis methods are preferred within the scope of this research is because of the databases in which scientific articles are indexed. It contains a large amount of unstructured data and standard statistical methods cannot be used in the analysis of this data. In this context, data were collected

within the scope of the study and then the data was structured with partial configuration and the big data analysis method was preferred.

Data Collection Process

Starting from 1965 to 2021, studies each published as a different XML file on the ERIC database in January 2022 were included in the scope of research. In this context, 1,873,751 studies published between the years 1965 and 2021 form the population of the research, and the number of studies taken into the scope of research for each year and a cumulative number of studies can be seen in Figure 1.

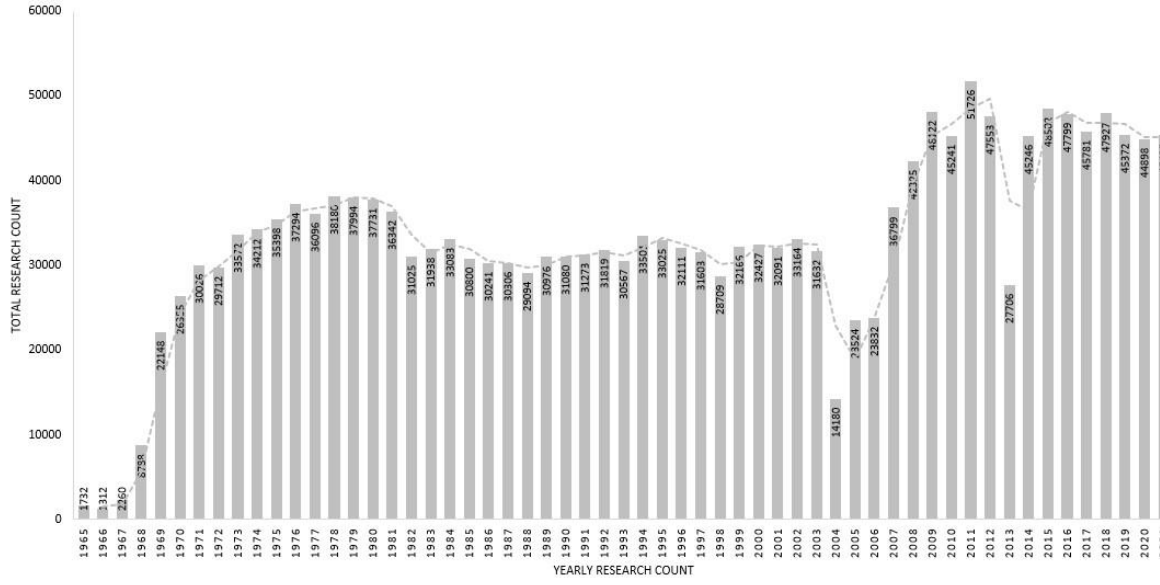

Figure 1. Annual and cumulative number of studies indexed on the ERIC database between years 1965-2021

Data Collection Tools

Within the study carried out, it aimed to analyze the studies indexed on the ERIC database in terms of different variables. To achieve this goal, article records indexed on the ERIC database were downloaded and saved from the ERIC index website (www.eric.ed.gov) so that each year could be a different XML file. After the process of saving, for the data gathered from ERIC to be processed easily in the following phases of the program, they were converted to The ElementTree XML API (https://docs.python.org/3/library/xml.etree.elementtree.html) benefiting from Python libraries and to Pandas (McKinney, 2010) data frame type benefiting from Pandas libraries and respectively,

1. Standardizing names of columns and cleaning unnecessary redundancies benefiting from Pandas libraries,

2. Changing column names benefiting from Pandas libraries,
3. The selection of data columns is only necessary for analysis by benefiting from Pandas libraries (İşbulan, Hamutoğlu & Kıyıcı, 2021).

After this process, the method based on the data collection and analysis process was carried out with the script used in the study of İşbulan, Hamutoğlu & Kıyıcı (2021) and Kıyıcı, Çukurbaşı & Çam (2021). Findings generated with the help of the script can be listed as follows;

1. Forming line charts of publications by year of publication found on data frames that are related to each single data frame sent into the script and forming lists of data in Microsoft Excel format,
2. Forming crosstab charts of publications research type information by years in the process of data gathering by ERIC staff on publications found in related data frames and for each data, a frame sent into Script.
3. Valid starting from the next three steps,
   a. Exclusion of punctuation marks from texts,
   b. Making all of the words in lowercase,
   c. Exclusion of frequent and unnecessary words from texts,

d. Making plural words singular, all of these actions were performed by using NLTK (Bird, Loper & Klein, 2009), one of the libraries of Python.

4. At this stage, the Python library, built-in on the address of https://github.com/amueller/word_cloud,was used for the formation of word clouds, for forming of word clouds from the titles of the publications found in related data frames and each data frame sent into the script and, forming of the word lists in Microsoft Excel format so that it can be useful for analysis.
5. At this stage, the Python library built-in on the address of https://github.com/amueller/word_cloud , was used for the formation of word clouds, the forming of word clouds from the abstracts of the publications found in related data frames and each data frame sent into the script and, forming of the word lists in Microsoft Excel format so that it can be useful for analysis.
6. At this stage, the Python library built-in on the address https://github.com/amueller/word_cloud , was used for the formation of word clouds, for the forming of word clouds generated from the Descriptor information of the publications selected by ERIC staff and found in related data frames and each data frame sent into the script and, forming of the word lists in Microsoft Excel format so that it can be useful for analysis.

For this research, “Robotics” was specified as the 1st level keyword which is used to describe the studies on ERIC Thesaurus and studies seen in the topic titles named as a

descriptor by ERIC. And as for 2nd level of keywords, "Educational Technology" and "STEM Education" words were specified in terms of the descriptor.

3. FINDINGS

The publication year intervals and the number of studies available in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics are given in Table 1.

Table 1

Year Intervals and Number of the Publications in the Three Subject Areas

Robotics		ET-in-Robotics		STEM-in-Robotics	
Publications Release Year Interval	*Number of Publications*	*Publications Release Year Interval*	*Number of Publications*	*Publications Release Year Interval*	*Number of Publications*
1973-2021	1339	1975-2021	241	2010-2021	215

As can be seen in Table 1, publications on Robotics have been available in ERIC since 1973 and between 1973 and 2021, 1339 studies have been added to the ERIC database. Studies on ET-in-Robotics have been available in ERIC since 1975 and between 1975 and 2021, 241 studies have been added ERIC database. Lastly, it has been found that studies on STEM-in-Robotics have been available in ERIC since 2010. This number reached 215 studies between 2010 and 2021. The distribution of studies published in ERIC related to Robotics, ET-in-Robotics, and STEM-in-Robotics according to publication years are given in Figure 5.

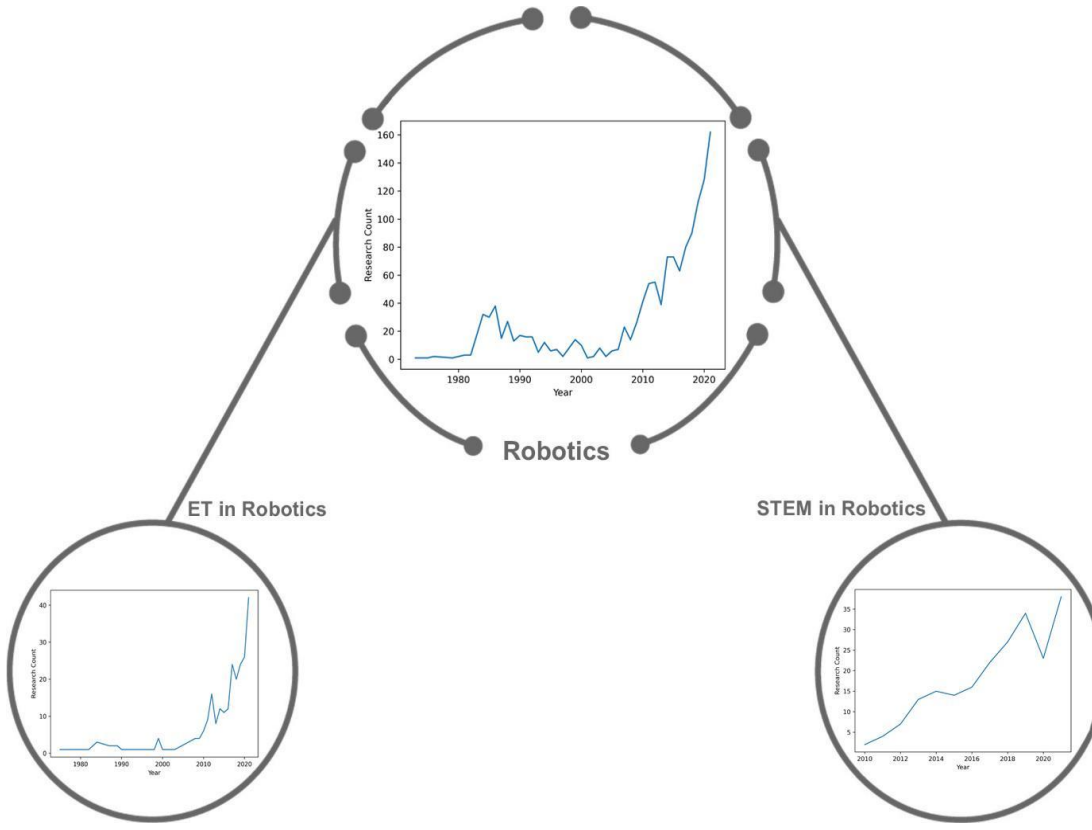

Figure 2. Distribution of Analysed Studies Published in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics by Years

When the distribution of the publications on Robotics given in Figure 2 is analyzed by years, in some periods, the number of related studies was high whereas it was low in some others, and 12.85% (N = 172) of these studies were between 1984 and 1990 and 58.33% (N = 781) of them were between 2014 and 2021. The distribution of publications on ET-in-Robotics by years revealed that the number of publications has been in a gradually increasing trend, and 70.95% (N = 171) of these studies were published in ERIC between 2014 and 2021. The number of these studies that were published before 2010 was found to be 31 (12.86%). On STEM-in-Robotics, it has been determined that the number of studies generally shows an increasing trend and 56.74% (N = 122) of these studies were published in ERIC between 2018 and 2021. When the distribution of the publications researched in the ERIC on the subject by years is analyzed, the following results are obtained:

- That when the graphs of distribution by years are analyzed publications on Robotics and ET-in-Robotics have been available in ERIC since 1973 and the annual publication graphics of these topics are similar,
- That the first study on STEM-in-Robotics published in ERIC was in 2010,

- That tough 241 studies have been published on ET-in-Robotics in ERIC since 1975, 215 studies have been published on STEM-in-Robotics since 2010,
- That the period between 2017 and 2021 represents the time when the number of studies on ET-in-Robotics and STEM-in-Robotics was the highest,
- That the number of studies published on ET-in-Robotics in ERIC has increased gradually in recent years, and more studies have been published in the period after 2017 than in the period before it,
- That the number of studies published on Robotics in ERIC has been steadily increasing especially in the last seven years ($N_{2014\text{-}2021}$=781; %58,33).

When the findings and results regarding the distribution of publications by years are examined, it has been observed that ET-in-Robotics is an increasingly popular subject that has been being researched for years and STEM-in-Robotics is among the current topics in Robotics. Also, the fact that the first study on STEM-in-Robotics became available in ERIC in 2010 and that the number of publications on ET-in-Robotics has been increasing since 2010 supports this result. In addition, the change and updating of the robotic systems for years because of the perpetual development of technology has a role in the fact that publications on robotics have been present for many years. The words used in the titles of the publications in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics have been analyzed. Thus, the 100 most frequently used words have been identified. The most frequently used 10 words and use frequency information obtained as a result of the analyzes for the three data groups are given in Table 2.

Table 2

The 10 Most Frequently Used Words in the Titles of the Studies analyzed in ERIC on the Three Subject Areas

Robotics ($f_{Robotics}$=4222)		ET-in-Robotics ($f_{ETinRobotics}$=865)		STEM-in-Robotics ($f_{STEMinRobotics}$=903)	
Top 10 Words	*f*	*Top 10 Words*	*f*	*Top 10 Words*	*f*
Robotics	367	Learning	60	Robotics	103
Robot	295	Robotics	57	STEM	69
Learning	210	Robot	53	Learning	38
Technology	169	Technology	47	School	35
Child	109	Teacher	27	Engineering	29
Teacher	107	Science	21	Technology	27
School	106	School	19	Robot	26
Programming	92	Programming	18	Science	22
Science	91	Teaching	18	Teacher	21
Teaching	82	Child	17	Program	18
fTotal	1628	fTotal	337	fTotal	388
%	38,56	%	38,96	%	42,97

When Table 2 was examined, it was identified that the most frequently used words on Robotics are "robotics" and "robot", which were followed by the words "learning", "technology", "child", and "teacher". In addition, it has been seen that concepts that are important for robotic studies, such as "school", "programming", "science", and "teaching" ranked high on the list and were frequently used. Secondly, it was identified that the most frequently used words in ET-in-Robotics studies are "learning" and "robotics", followed by "robot", "technology", and "teacher". Also, it has been revealed that concepts such as "teaching", “programming” and "child", which can be considered important for ET ranked high on the list and are used frequently. Finally, it has been observed that the most frequently used words in STEM-in-Robotics studies are "robotics" and "STEM", followed by "learning" and "school". In addition, it has been revealed that concepts such as "engineering, "technology", “robot”, “science”, “teacher” and "program", which can be seen as important for STEM, ranked high on the list/of frequently used. The findings obtained after the analysis of the titles of the publications on the three subject areas have been presented in Figure 3 in the form of a word cloud.

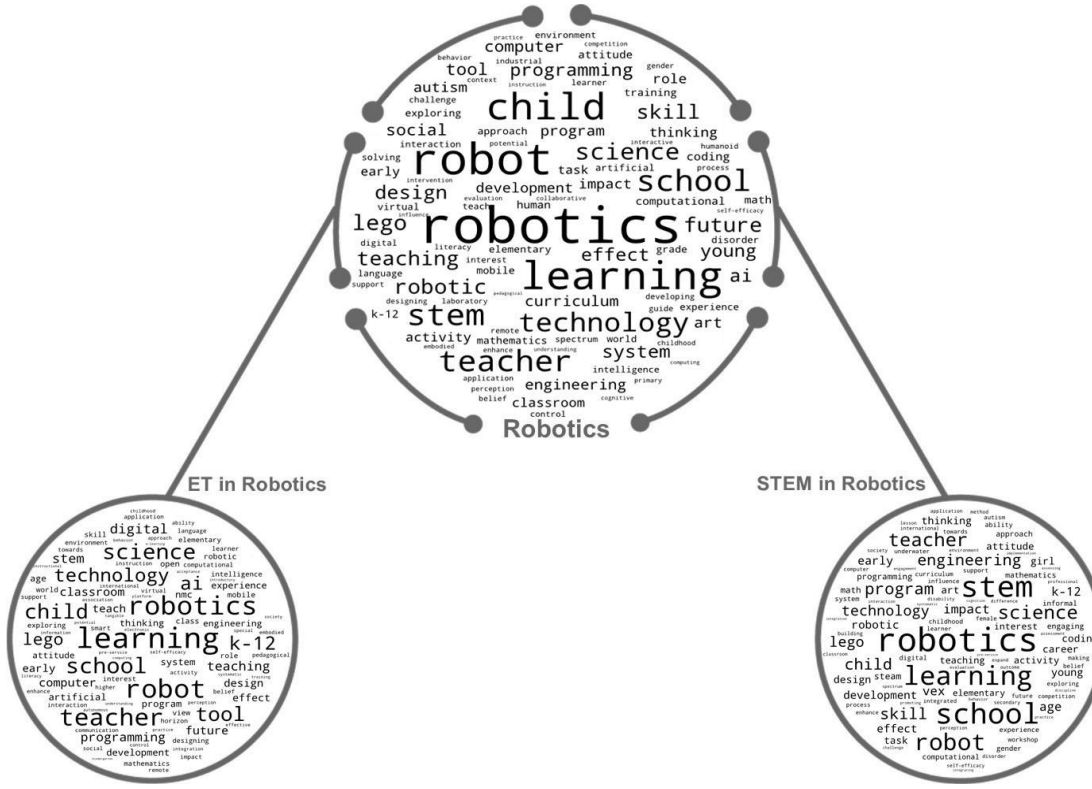

Figure 3. The Word Cloud Representation of the Content Analysis Results of the Titles

When Figure 3 was examined, it is seen that the words "robotics" and "learning" are frequently used in all three subject areas. In addition to these words, the words “robotics” "school", "robot", “stem” and "engineering" are prominent in STEM-in-Robotics. As for Robotics, there were no other prominent words other than "robotics",

“learning” and "robot". However, when examined in detail, it has been determined that the words "child", "school", "stem", “science” and "teacher" in Robotics and “robotics”, “technology”, "science", "child", “school”, “robot” and "teacher" in ET-in-Robotics are more frequently used than others. Although the words "robotics", "learning" and "child" are the most frequently used in the titles of studies on Robotics and ET-in-Robotics, in the titles of STEM-in-Robotics publications, the word "robotics" and “stem” has been seen to be prominent.

When the word cloud given in Figure 6 was examined in detail, it is seen that although the titles on Robotics include words such as "curriculum", "young", "autism", "humanoid", "collaborative", "challenge", and "coding", these words are not used on ET-in-Robotics. Similarly, although the titles of studies on Robotics include words such as "social", "virtual", "artificial", "mobile", "humanoid", and "collaborative", these words are not included in the titles of STEM-in-Robotics. In addition, concepts that are used in the titles of studies on ET-in-Robotics such as "communication", "horizon", "class", "instructional", "e-learning" and “kindergarten” are not found in other titles. Finally, in the titles of publications on STEM-in-Robotics, unlike other subject areas, it has been found that words such as "engaging", "informal", "workshop", "career", "integrated", "building", “implementation” and "disability" were used.

The word "LEGO", which is the name of one of the sets used in robotic applications, is among the frequently used words in the titles. The 29nd most frequently used word in Robotics study findings has been (f_{LEGO}=38), the 24th most frequently used word in ET-in-Robotics study findings has been (f_{LEGO}=9) and the 27th most frequently used word in STEM-in-Robotics study findings has been (f_{LEGO}=8). Among the 100 most frequently used words in the titles of studies on Robotics and ET-in-Robotics, no robotic set name other than LEGO is included, but it has been revealed that in the titles of studies on STEM-in-Robotics, in addition to LEGO, robotic product names VEX and Tinker Bot are also used.

While the word "student" is not among the most frequently used 100 words in the titles of studies on Robotics, the word "teacher" ranked 5th (f = 107) words such as "child", "childhood", "k-12", and "young", which can be considered as alternatives to "student", are among the 100 most frequently used words. Similarly, "student" was not among the 100 most frequently used words in the titles of studies on ET-in-Robotics. But, the word "teacher" (f = 27) ranked 5th. As an alternative to the word "student", the words "child", "k-12", and "learner" are among the words used. Finally, while "student" is not included among the 100 most frequently used words in the titles of studies on STEM-in-Robotics, the word "teacher" ranked 9th (f = 21). In addition, the words "child", "k-12", "girl", and "young", which can be considered to be alternatives to the word "student", are among the findings.

In Table 3, the number of different words used in the titles of studies on the three subject areas and their frequencies is given.

Table 3

Table of Number of Different Words in the Three Subject Areas

	Robotics	ET-in-Robotics	STEM-in-Robotics
Robotics		29 (f=627)	36 (f=746)
ET-in-Robotics	29 (f=110)		43 (f=194)
STEM-in-Robotics	36 (f=140)	43 (f=178)	

When Table 3 was examined, it has been determined that in the titles of publications on Robotics and ET-in-Robotics 29 different words were used ($f_{Robotics}$=627; $f_{ETinRobotics}$=110), in the titles of the publications on Robotics and STEM-in-Robotics 36 different words were used ($f_{Robotics}$=746; $f_{STEMinRobotics}$=140), and in the titles of publications on ET-in-Robotics and STEM-in-Robotics 43 different words were used ($f_{ETinRobotics}$=194; $f_{STEMinRobotics}$=178). When the three data groups were compared, it has been revealed that mostly different words were used in the titles of ET-in-Robotics and STEM-in-Robotics publications. When the words in the titles of the studies published in ERIC in three finding categories are compared (by filtering conjunctions and unrelated words), the number and frequencies of the same words are given in Table 4.

Table 4

Table of Number of Same Words/Findings in the Titles of the Studies in the Three Subject Areas

	ET-in-Robotics	STEM-in-Robotics
Robotics	71 (f=3595-755)	64 (f=3476-763)
ET-in-Robotics		57 (f=671-725)

Table 4 displayed that 71 words in the titles of the Robotics and ET-in-Robotics publications ($f_{Robotics}$=3595; $f_{ETinRobotics}$=755), 64 words in the titles of the Robotics and STEM-in-Robotics publications ($f_{Robotics}$=3476; $f_{STEMinRobotics}$=763) and 57 words in the titles of ET-in-Robotics and STEM-in-Robotics publications ($f_{ETinRobotics}$=671; $f_{STEMinRobotics}$=725) were the same. When Table 3 and Table 4 were compared, it has been found that the similarities in the titles of Robotics and ET-in-Robotics publications were more, and the similarities in ET-in-Robotics and STEM-in-Robotics publications were less. The following results are obtained after the analysis of the titles of the studies in the three subject areas:

- When ET-in-Robotics findings are removed from the Robotics findings, more words containing cognitive processes (such as curriculum, social, activity, training, industrial, competition, collaborative, interest, behavior, cognitive, building, computational, assessment, strategy, simulation, math, difference) remained; and

when the STEM-in-Robotics findings are removed, more concepts about robotic studies in technical engineering fields, such as intelligence, industrial, training, guide, virtual, control, mobile, machine, manufacturing, action, humanoid, technician, introductory and remote, remained. Therefore, it has been found that compared to the STEM-in-Robotics studies, the studies published in ERIC on ET-in-Robotics differ more in terms of their titles.

- The word LEGO, which is the name of one of the robotic sets, is included in the titles in the studies of all three data groups, and VEX and Tinker Bot, which are among the other robotic sets, are among the 100 most frequently used words only in the titles of STEM-in-Robotics studies.
- The word LEGO has been used more frequently in Robotics publications; so in Robotics studies, LEGO sets are used more than other robotic sets.
- More specific concepts were included in the titles of the studies in ERIC on STEM-in-Robotics.
- When the titles of the studies published in ERIC on STEM-in-Robotics are examined in detail, robotic activities are considered teaching technology.
- Words "science", "engineering", "programming", and "design", which are a part of the concept of STEM, are among the most frequently used words in the titles of Robotics publications.
- Unlike STEM-in-Robotics findings, in ET-in-Robotics findings, words such as "language", "literacy", "artificial", "virtual", "communication", "e-learning", and "integrating" come to the fore.
- In the STEM-in-Robotics findings, contrary to ET-in-Robotics findings, it has been found that the concepts of "competition", "computational", "thinking", "task", "activity", "self-efficacy", "engagement", and "curriculum" are among the prominent words.

When the analysis results of the words used in the titles were examined, robotics was considered an educational technology in ET-in-Robotics studies. And, in STEM-in-Robotics studies, robotics was conceived as a STEM tool, and more focus was given to robotic teaching activities. In addition, most of the studies researched in ERIC on ET-in-Robotics and STEM-in-Robotics are differentiated from each other and this has been clearly demonstrated in the tables of difference. Also, the studies researched in ERIC on ET-in-Robotics and STEM-in-Robotics can be clearly differentiated as well. The analysis of the titles of the existing studies has yielded findings that will guide the researchers who will conduct studies on these subject areas.

The words used in the abstracts of the publications in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics have been analyzed and the 100 most frequently used words have been found. The most frequently used 10 words and frequency information obtained as a result of the analyzes for the three data groups are given in Table 5.

Table 5

The 10 Most Frequently Used Words in the Abstracts of the Studies Researched in ERIC on the Three Subject Areas

Robotics (fRobotics=25674)		ET-in-Robotics (fETinR=5718)		STEM-in-Robotics (fSTEMinR=5984)	
Top 10 Words	*f*	*Top 10 Words*	*f*	*Top 10 Words*	*f*
Learning	1203	Learning	333	Robotics	337
Robotics	1197	Technology	305	STEM	333
Robot	1179	Robot	228	School	228
Technology	794	Robotics	221	Learning	193
School	658	Teacher	166	Program	183
Teacher	595	Science	112	Teacher	173
Design	553	Design	111	Engineering	154
Program	529	School	110	Science	127
Science	501	Teaching	109	Technology	124
Child	497	Development	99	Robot	114
fToplam	7706	fToplam	1794	fToplam	1966
%	30,01	%	31,37	%	32,85

According to Table 5, firstly, the most frequently used words in Robotics studies were "learning" and "robotics", followed by "robot", "technology", and "school". In addition, words such as "teacher", "design", “program”, “science” and "child", which are important for robotic applications, ranked high on the list and were frequently used. Secondly, it has been observed that the most frequently used words in ET-in-Robotics publications were "learning" and "technology", followed by "robot", "robotics", and "teacher". Also, it has been revealed that concepts such as "science" and "design", which can be seen as important for ET ranked high on the list and were used frequently. Finally, it has been observed that the most frequently used words used in STEM-in-Robotics studies were "robotics" and "STEM", followed by "school", "learning", and "program". It has been revealed that in addition to these words, concepts that are prominent in the field of STEM, such as "teacher", "engineering", "science", and "technology" ranked high on the list/of frequently used.

Numerical information about the analysis of abstracts of the studies reviewed in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics (filtering conjunction and unrelated words) is given in Table 6.

Table 6

Numerical Information about the Analysis of the Abstracts of Studies in the Three Subject Areas

Robotics	ET-in-Robotics	STEM-in-Robotics
Frequency of 100 Most Common Words	*Frequency of 100 Most Common Words*	*Frequency of 100 Most Common Words*
25674	5718	5984

Table 6 showed that the usage frequency of the 100 most frequently used words determined with the content analysis of the abstracts of the studies in ERIC was calculated as (f) 25674 for the descriptor of "Robotics", as 5718 for the descriptor of "ET-in-Robotics", and as 5984 for the descriptor of "STEM-in-Robotics". The word cloud representation of the findings obtained after the comparison of the content analyzes of the abstracts of the publications on the three subject areas has been presented in Figure 4.

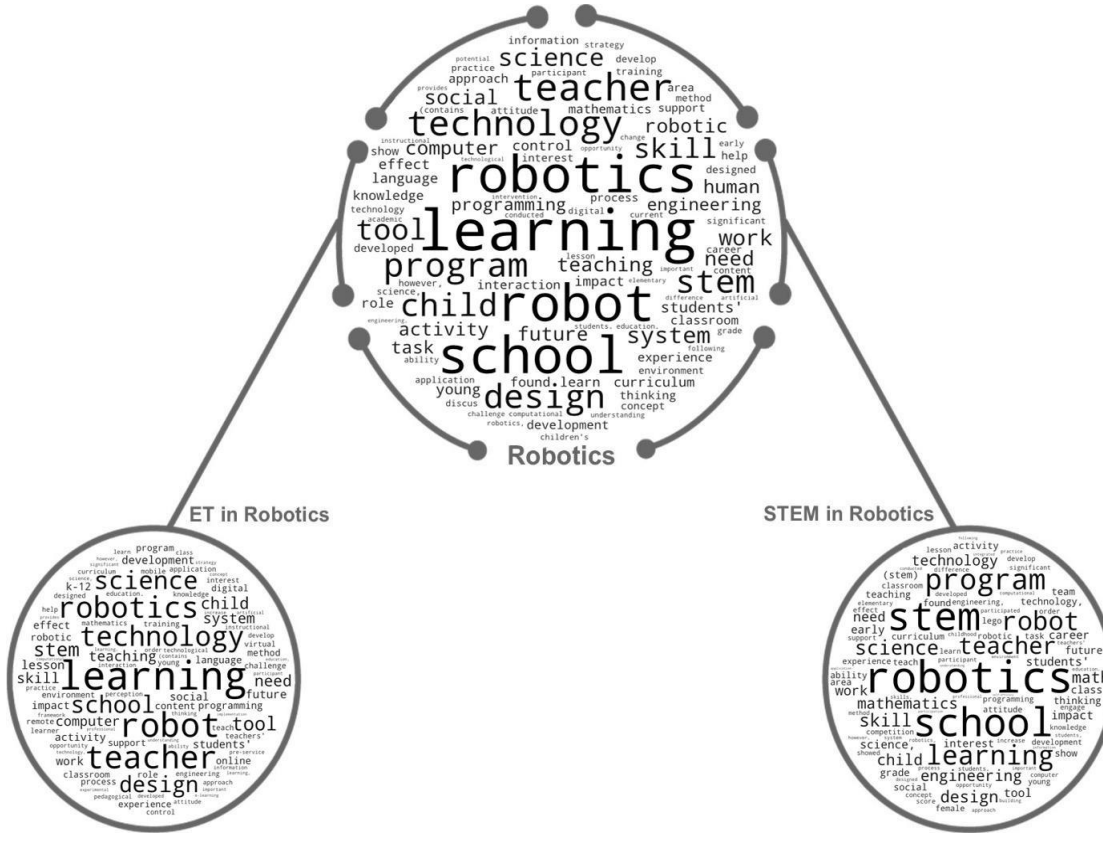

Figure 4. *Word Cloud Representation of the Content Analysis Results of the Abstracts*

When Figure 4 was examined, it has been seen that the word "learning" was the most frequently used word in two subject areas. In addition, it has been seen that in Robotics, the words "robotics", "robot", "technology", "school", "teacher", "design", "program", "science" and "child"; in ET-in-Robotics, the words "technology", "robot", "robotics", and "science" stood out. On the other hand, in STEM-in-Robotics studies, no prominent words have been found except "robotics" and "STEM". However, examined in detail, it has been found that the words "school", "learning", "engineering", "teacher", and "program" were used more than other words.

Although the words "learning" was the most frequently used word in the abstracts of the publications on Robotics and ET-in-Robotics, in the abstracts of STEM-in-Robotics publications, this word was replaced by "robotics".

In Table 7, the number and frequencies of different words used in the abstracts of the studies on the three subject areas (conjunction and unrelated words are filtered) are given in Table 7.

Table 7

Table of Number of Different Words/Findings in the Three Research Areas

	Robotics	ET-in-Robotics	STEM-in-Robotics
Robotics		22 (f=3115)	23 (f=3547)
ET-in-Robotics	22 (f=778)		31 (f=1124)
STEM-in-Robotics	23 (f=1197)	31 (f=1020)	

As Table 7 shows, in abstracts of the Robotics and ET-in-Robotics publications 22 words ($f_{Robotics}$=3115; $f_{ETinRobotics}$=778), in the abstracts of Robotics and STEM-in-Robotics publications 23 words ($f_{Robotics}$=3547; $f_{STEMinRobotics}$=1197), and the abstracts of ET-in-Robotics and STEM-in-Robotics publications 31 different words ($f_{ETinRobotics}$=1124; $f_{STEMinRobotics}$=1020) were different. When the three data groups were compared, fewer different words were used in the abstracts of Robotics and ET-in-Robotics publications, and more different words were used in the abstracts of ET-in-Robotics and STEM-in-Robotics publications. When the words in the abstracts of the studies published in ERIC in three finding categories are compared (by filtering conjunctions and unrelated words), the number and frequencies of the same words are given in Table 8.

Table 8

Table of Number of Same Words/Findings in the Titles of the Studies in the Three Subject Areas

	ET-in-Robotics	STEM-in-Robotics
Robotics	78 (f=22559-4940)	77 (f=22127-5226)
ET-in-Robotics		69 (f=4521-4860)

When Table 8 was examined, it has been determined that 78 words in the abstracts of the Robotics and ET-in-Robotics publications ($f_{Robotics}$=22559; $f_{ETinRobotics}$=4940), 77 words in the abstracts of the Robotics and STEM-in-Robotics publications ($f_{Robotics}$=22127; $f_{STEMinRobotics}$=5226) and 69 words in the abstracts of ET-in-Robotics and STEM-in-Robotics publications ($f_{ETinRobotics}$=4521; $f_{STEMinRobotics}$=4860) were the same.

When Table 7 and Table 8 were compared, the level of similarity between the abstracts of Robotics and ET-in-Robotics publications was higher and the level of similarity between the ET-in-Robotics and STEM-in-Robotics study abstracts was lower.

When word clouds given in Figure 7 are examined in detail, although the words in the abstracts of Robotics studies include words such as "human", "task", "elementary", "technical", and "material", these words were not included the abstracts of the ET-in-Robotics studies. Similarly, although words such as "language", "interaction", "training", "systems", and "human" are used in the studies on Robotics, these words were not included in the abstracts of the STEM-in-Robotics studies. In addition, words such as "online", "pedagogical", "e-learning", "learner", and "virtual" in ET-in-Robotics findings have not been found in the other findings. Lastly, in the findings of STEM-in-Robotics as being different from the other findings words such as "math", "participated", "building", " self-efficacy" and "engage" have been identified. The following results are achieved after the analysis of the abstracts of the studies in the three subject areas:

- When ET-in-Robotics findings are removed from robotics findings, more technical words (such as robots, systems, manufacturing, industry, industrial, technical, unit, and artificial) remained; and when the STEM-in-Robotics findings were extracted, in addition to the technical words, terms such as "language", "interaction", "application", "evaluation", "strategy", "performance", and "material", which are concepts within the scope of learning activities / educational technologies, were used. Therefore, publications reviewed in ERIC on ET-in-Robotics represent Robotics more compared to the publications reviewed on STEM-in-Robotics.
- The words "science", "engineering", "programming", and "design", which are a part of the concept of STEM, are among the most frequently used words in the abstracts of Robotics publications.
- Unlike STEM-in-Robotics findings, in ET-in-Robotics findings, words such as "language", "online", "application", "interaction", and "virtual" come to the fore.
- Unlike ET-in-Robotics findings, in STEM-in-Robotics findings, words such as "competition", "career", "math", "elementary", and "early" were among prominent words.

When the results of the analysis of the publications' abstracts are taken into consideration, the studies on STEM-in-Robotics in ERIC focus on more specific subjects. And, when the abstracts of these studies are examined in detail, they took robotic activities as teaching technology. In ET-in-Robotics studies, on the other hand, robotics was considered as educational technology, while in STEM-in-Robotics studies it was examined as a STEM tool. Words such as "application", "interaction", "training", "instructional", "e-learning", "practice", "experimental", and "performance", were used especially in ET-in-Robotics studies unlike STEM-in-Robotics studies, and words such as "competition", "career", "math", "participant", "building", "team", "implementation", and "attendance", which were used more frequently in STEM-in-Robotics studies unlike ET-

in-Robotics studies helped reveal this situation. Also, most of the studies reviewed in ERIC on ET-in-Robotics and STEM-in-Robotics differed from each other. This situation has been clearly demonstrated by difference/similarity tables. Also, it is possible to distinguish between the studies reviewed in ERIC on ET-in-Robotics and STEM-in-Robotics in light of the findings.

Descriptors assigned to the reviewed studies on Robotics, STEM-in-Robotics, and STEM-in-Robotics in ERIC by the ERIC staff have been analyzed. Therefore, 2000 ($f_{Robotics}$=18001) descriptors to Robotics studies, 490 ($f_{ETinRobotics}$=3760) descriptors to ET-in-Robotics studies, and 432 ($f_{STEMinRobotics}$=3469) descriptors to STEM-in-Robotics studies were assigned. The most frequently used 10 descriptors and use frequency information obtained as a result of the analyses for the three data groups are given in Table 9.

Table 9

The 10 Most Frequently Assigned Descriptors to the Studies Analysed in ERIC on the Three Subject Areas

Robotics		ET-in-Robotics		STEM-in-Robotics	
Top 10 Descriptors	*f*	*Top 10 Descriptors*	*f*	*Top 10 Descriptors*	f
Teaching Methods	367	Teaching Methods	116	Teaching Methods	73
Educational Technology	242	Technology Uses in Education	103	Student Attitudes	52
STEM Education	215	Programming	43	Elementary School Students	46
Programming	205	STEM Education	43	Educational Technology	43
Technology Uses in Education	194	Student Attitudes	42	Programming	41
Student Attitudes	184	Elementary Secondary Education	32	High School Students	39
Engineering Education	161	Program Effectiveness	29	Middle School Students	38
Elementary School Students	153	Technology Integration	28	Engineering Education	34
Problem Solving	149	Artificial Intelligence	28	Program Effectiveness	33
Computer Science Education	130	Instructional Effectiveness	26	Problem Solving	33
fToplam	2000	fToplam	490	fToplam	432
%	11,83	%	13,36	%	12,45

Table 9 revealed that "teaching methods" is the most frequently assigned descriptor for all three data groups. In addition, the most frequently assigned descriptors were "educational technology", "STEM education", "programming", " technology uses in education", and "student attitudes" for Robotics studies, "technology uses in education", "programming", "STEM education", and "students attitudes" for ET-in-Robotics studies, and "student attitudes", "elementary school students", "educational technology", and

"programming" for STEM-in-Robotics studies. Numerical information about descriptors assigned to studies analyzed in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics are given in Table 10.

Table 10

Numerical Information About the Subjects of Publications in the Three Subject Areas

Robotics		ET-in-Robotics		STEM-in-Robotics	
Top 10 Descriptor	f	Top 10 Descriptor	f	Top 10 Descriptor	f
2000	18001	490	3760	432	3469

When Table 10 is examined, there are 1854 different (f = 11661) descriptors assigned to the studies analyzed in ERIC on Robotics. In addition, it has been observed that 751 different descriptors to the ET-in-Robotics studies (f = 2159) and 627 different descriptors to the STEM-in-Robotics studies (f = 1741) were assigned. When all descriptors are compared, it has been found that descriptors assigned to Robotics match descriptors assigned to other subjects, too. The word cloud representation of the findings obtained from the comparison of descriptors assigned to studies analyzed in ERIC on Robotics, ET-in-Robotics, and STEM-in-Robotics is given in Figure 8.

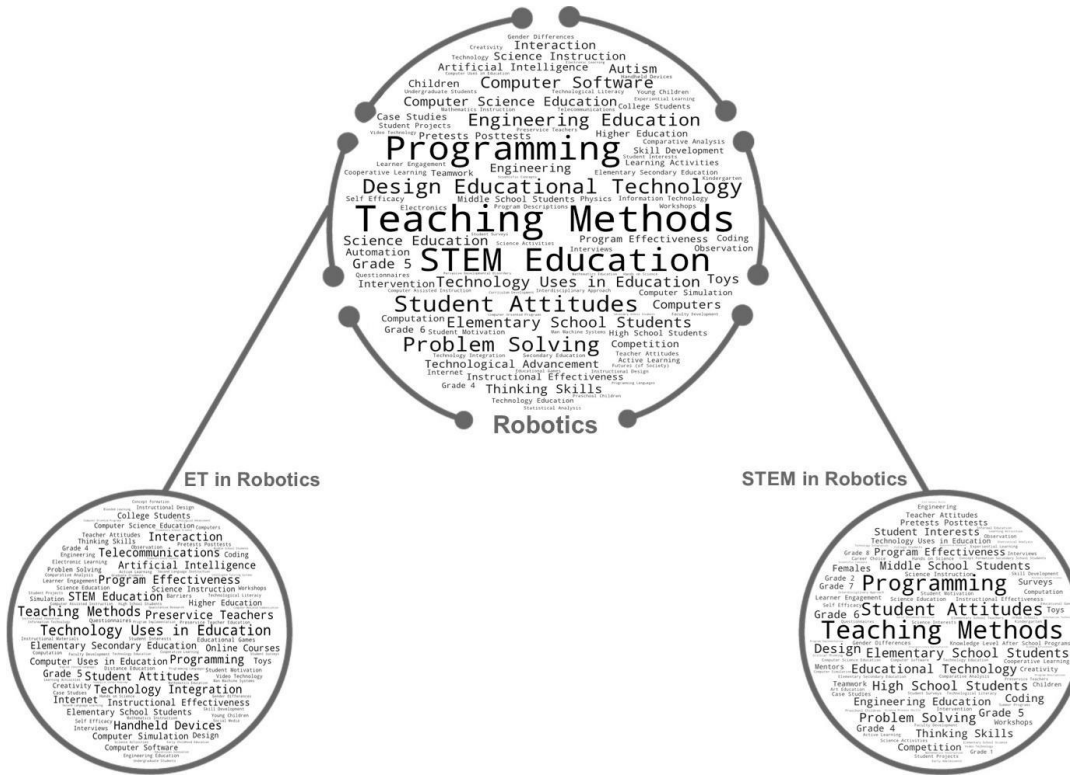

Figure 5. The Word Cloud Representations of the Analysis Results of the Descriptors

When the frequently used descriptors in the word clouds created for the three finding categories in Figure 5 were examined, the most prominent descriptor is "teaching methods". In addition, the descriptors of "education technology", "STEM education", and "programming" came to the fore in the Robotics studies while the descriptors "technology uses in education", "programming", and "STEM education" in ET-in-Robotics studies and the descriptors "student attitudes", "elementary school student", "educational technology", and "programming" in STEM-in-Robotics studies have been found to be prominent. Also, in the ET-in-Robotics studies, the level of use of the descriptors "teaching methods" and "technology uses in education" has been found to be distinctively higher than the others, and different descriptors came to the fore in ET-in-Robotics and STEM-in-Robotics studies.

Descriptors such as "middle school students", "high school students", "elementary school students", and "student attitudes" were prominent in the word cloud of STEM-in-Robotics. This situation indicates that, in contrast to ET-in-Robotics studies, research with the participation of more students has been carried out in STEM-in-Robotics studies. On the other hand, it has been determined when the descriptors of the ET-in-Robotics studies were examined that a similar number of descriptors as Robotics studies were used, and in studies analyzed in ERIC on these subject areas, the teaching methods and techniques in robotics were investigated, unlike the STEM-in-Robotics studies.

The number of descriptors that are used for the studies of one subject area but not used for another found after the findings of the three finding categories in Figure 8 were compared is given in Table 11.

Table 11

Table of Number of Different Words/Findings in the Descriptors of the Studies in the Three Subject Areas

	Robotics	ET-in-Robotics	STEM-in-Robotics
Robotics		1176 (f=2758)	1249 (f=3260)
ET-in-Robotics	0		353 (f=513)
STEM-in-Robotics	0	280 (f=390)	

According to Table 11, 1176 of the descriptors assigned to Robotics studies (f = 2758) and 1249 of the descriptors assigned to ET-in-Robotics studies (f = 3260) were not assigned to studies on STEM-in-Robotics in ERIC. Also, 353 of the descriptors assigned to ET-in-Robotics studies (f = 513) were not assigned to STEM-in-Robotics publications. Conversely, it has been observed that there are 280 (f = 390) descriptors assigned to STEM-in-Robotics studies but not ET-in-Robotics studies. The same number of descriptors identified when the findings obtained within the three finding categories are compared is given in Table 12.

Table 12

Table of Number of Same Words/Findings in the Descriptors of the Studies in the Three Subject Areas

	ET-in-Robotics	STEM-in-Robotics
Robotics	912 (f=15243-3760)	839 (f=14741-3469)
ET-in-Robotics		559 (f=3247-3079)

Table 12 revealed that 912 of the 2000 different descriptors assigned to the publications in ERIC on Robotics were the same as descriptors assigned to ET-in-Robotics studies ($f_{Robotics}$= 15243; $f_{ET\text{-}in\text{-}Robotics}$= 3760), and 839 of them were the same with descriptors assigned to STEM-in-Robotics publications ($f_{Robotics}$= 14741; $f_{STEM\text{-}in\text{-}Robotics}$= 3469). In addition, it has been found that among the descriptors assigned to ET-in-Robotics and STEM-in-Robotics studies in ERIC, 559 descriptors were the same ($f_{ET\text{-}in\text{-}Robotics}$= 3247; $f_{STEM\text{-}in\text{-}Robotics}$ = 3079).

When the word clouds given in Figure 8 were examined, it has been observed that 1176 descriptors, especially "student evaluation", "competency-based education", "educational needs", "electronic control", “integrated curriculum” and "employment opportunities", were assigned only to studies on Robotics studies but not to STEM-in-Robotics studies. Also, 1249 different descriptors were assigned to Robotics studies but not to STEM-in-Robotics studies, chiefly "futures (of society)", "man-machine systems", "microcomputers", "computer science", and "course descriptions". On the other hand, all descriptors assigned to ET-in-Robotics and STEM-in-Robotics publications were assigned to studies on Robotics.

When the descriptors assigned to Robotic and STEM-in-Robotics studies are compared, 353 different descriptors assigned to the ET-in-Robotics studies, chiefly "distance education", "instructional innovation", "man-machine systems", "educational media", and "simulated environment", were not assigned to STEM-in-Robotics publications. Also, 280 different descriptors assigned to the STEM-in-Robotics studies, chiefly "career choice", "preschool children", "secondary school students", "student evaluation", and "extension education", were not assigned to ET-in-Robotics studies. When the most frequently assigned descriptors to the studies of the three subject areas are examined, the following results are obtained:

- In the context of Robotics, studies on teaching methods, engineering education, technological developments, programming, student attitudes, the technology uses in education, problem-solving and computer science education are frequently conducted.
- In the context of ET-in-Robotics, most studies on teaching methods, the technology used in education, programming, technology integration, student attitudes, artificial

intelligence, program effectiveness, instructional effectiveness, and STEM education are carried out.

- In the context of STEM-in-Robotics, studies are mostly on teaching methods, student attitudes, engineering education, program effectiveness, programming, and problem-solving.
- The most frequently researched target groups are the K-12 and higher education students in Robotics studies, primary school and middle school students in ET-in-Robotics studies, and the K-12 students in the STEM-in-Robotics studies.
- That unlike the subjects ET-in-Robotics studies, STEM-in-Robotics studies generally focus on the subjects of career choice, science careers, summer science programs, and non-formal education,
- That unlike the subjects of STEM-in-Robotics studies, in studies on ET-in-Robotics, the topics of distance education, innovation in education, educational media, simulated environments, learning strategies, computer networks, and virtual classes are focused on,
- That in the publications on ET-in-Robotics and STEM-in-Robotics, the commonly searched subjects are teaching methods, the technology uses in education, programming, the use of computers in education, the effectiveness of teaching, and student attitudes,

Robotics is the most frequently used area as a teaching method among the three groups; therefore, the studies in ERIC on Robotics mostly deal with the subject of teaching methods. In addition, teaching methods, engineering education, technological developments, programming, and student attitudes have been observed to be the most researched subjects. It has been determined that the subjects of computer use in education, the effectiveness of teaching, and the use of technology in education are mostly examined in publications related to ET-in-Robotics. Moreover, there are very few publications on these issues in the STEM-in-Robotics field. When the descriptors that may be related to the robotic competitions held worldwide are examined, they are mostly assigned to publications on STEM-in-Robotics, and very few of them were assigned to ET-in-Robotics studies. Topics such as student interest fields, engineering, and design have been explored more in studies on STEM-in-Robotics than on ET-in-Robotics.

4. RESULTS, DISCUSSIONS, AND SUGGESTIONS

In the scope of the current study, studies analyzed Robotics in ERIC dating to 1973. Although the number of publications went up and down over the years, compared to its prior, more publications on this subject were analyzed in ERIC after the 2000s compared to its prior. Especially the increase in the number of studies on Robotics in recent years shows that it is one of the current subjects of the era. Also, over time, new subject areas

such as ET-in-Robotics and STEM-in-Robotics have emerged, and research has been frequently conducted on these topics as well.

When the titles of the studies analyzed in ERIC on this topic are examined, the concept of "learning", which is frequently used in titles, is important. And that the other most frequently used words give information about the subject area of a study. These words are "robot", "teaching", "school", “science”, “child” and "teacher" for ET-in-Robotics studies and "school", "engineering", "STEM", and "program" for STEM-in-Robotics studies. Moreover, in all subject areas, the word "LEGO", which is the name of one of the robot kits, is used, while the names of robot kits such as VEX and Tinker Bot are also used in studies on STEM-in-Robotics. Finally, when the words frequently used in the titles for the three subject areas were analyzed in terms of their difference and similarity, the similarities and differences consisted of words specific to the subjects and differed specifically to the subject areas.

After the content analysis of the abstracts of the publications, it has been determined that the words "learning" and "robotics" in Robotics and ET-in-Robotics studies. Also, the words "STEM", "school", "science", “program” and "engineering" in STEM-in-Robotics studies were frequently used. When the words used in the abstracts of studies on Robotics are filtered, only technical expressions remain. In addition, it has been found that publications on ET-in-Robotics represent Robotics more than publications on STEM-in-Robotics. Also, the separation of the studies analyzed in ERIC on these two subjects can be made easily.

Among the descriptors assigned to the publications by ERIC staff, the most frequently used descriptor is "teaching methods" in all three subject areas. When the descriptors were examined in detail, it has been found that STEM-in-Robotics studies were carried out with different student groups, unlike ET-in-Robotics studies. It has been seen that the most frequently researched student groups are the K-12 and higher education students in Robotics studies, primary school and middle school students in ET-in-Robotics studies, and the K-12 in STEM-in-Robotics studies. Conversely, in the Robotics and ET-in-Robotics subjects, teaching methods and techniques used in the teaching of robotics are mostly examined. The descriptors assigned to Robotics studies include the descriptors assigned to publications on ET-in-Robotics and STEM-in-Robotics as well.

The subject of Robotics gains new features in line with technological developments and provides new research problems for researchers. Especially after the 2000s, the acceleration of technological developments has been effective in increasing the number of publications on Robotics. Therefore, it is expected that new subject areas related to the subject of Robotics will emerge and new research will be carried out today and in the future.

This study is a guide that enables researchers who will carry out studies on Robotics to customize their research according to the subject area. In addition, it is believed that the study would make important contributions to the planning process for researchers who

will study ET-in-Robotics or STEM-in-Robotics. The few publications in the literature on the content analysis of the existing studies on Robotics have been examined. Therefore, setting out the process that started with the first publication on the subject in ERIC enables researchers to see the bigger picture of the developments in the field of Robotics. It is suggested that in future studies, the research on Robotics be carried out by expanding it to its sub-topics.

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