PROJECT-BASED LEARNING IN SCIENCE EDUCATION: A BIBLIOMETRIC NETWORK ANALYSIS

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Abstract

The project-based learning model is the most common method used concerning transferring knowledge and skills gained from the courses of sciences to the daily lives of students. Through the relevant method, science courses are considered to be more efficient and understandable as well as to be more loved by the students. In this respect, it is of great importance to periodically examine the research on project-based learning in science education and to identify trends. In this study, it was aimed to determine the content analysis and trends of the studies on project-based learning in science education. First, we registered 885 publications using "science education and project-based learning" in the "Social Sciences" category from Scopus, documents were then exported to CSV form and in turn, subjected to the bibliometric analysis using VOSviewer Software. In addition, the bibliometrix program was used for Lotka's law and author effect ratio.

Keywords: Project-based learning, Bibliometric analysis, VOSviewer, Scopus

INTRODUCTION

Today changes in science and technology touch and change the lives of individuals very quickly. New information and inventions found in any country of the world are obtained very quickly by people in other countries through the Internet. The flow of information continues at the same pace in studies related to education training. Today, research education reveals that students learn better when they are at the center of information and actively access information. In recent years, studies in the field of science and mathematics education in our country focus on the effects of various learning approaches on students' learning. Among these, it is striking that the learning approaches in which students actively construct knowledge and work together come to the fore. When students are at the center of learning and connected with knowledge, they reach higher levels of thinking more easily. Education specialists around the world have abandoned the traditional understanding of education training developed classical methods and provided the construction of new and contemporary methods and approaches. Today, the main goal of finding applications of new methods and approaches in many countries is known that it contributes to the teaching processes as well as realizing permanent learning in the student. One of these contemporary approaches is the project-based learning approach.

Project-based learning is a form of study in which students conduct research and investigations as a group, report the information, and present the data they have obtained as a concrete product or work (Yıldız, 2009). In other words, project-based learning is a learning approach in which students try to solve the problems they may encounter within the framework of a scenario by connecting with different disciplines in the classroom environment. Project-based learning has very distinctive features. Perhaps the most emphasised feature is that the student and teacher design the project together. Teacher and student work together on a specific scenario, trying to find a solution to a real problem. In this search for a solution, there may often be no solution. Students and teachers think and evaluate more than one solution together. Evaluating more than one solution and searching for different solutions gives both students and teachers certain skills. The main purpose of this method is to enable students to produce solutions to daily life problems, using a scientific approach, together with their peers and under the guidance of their teachers. In other words, in project-based learning, students are expected to look for a solution to a real problem by presenting scenarios or slices of life. The method requires teachers to identify projects that encourage students to create plans individually or in groups, solve the problems they encounter, test their ideas, and present their projects to their peers (Wurdinger, Haar, Hugg & Bezon, 2008).

All of the developed countries in the world are in an effort to increase the quality of science education. Because science enables people to understand the nature they live in, and technology enables them to make changes that will make our lives easier in accordance with the rules of nature (Çepni, Ayas, Akdeniz, Özmen, Yiğit & Ayvacı, 2005). The project-based learning model comes first among the methods that can be used in order for students to transfer the knowledge and skills they have gained in science lessons to daily life and to cope with the new problems they encounter every day. Science course especially allows the use of Project Based Learning Approach (PBL). It is thought that using this method in science lessons is effective in making this lesson more efficient and understandable, and also in making it more liked by students. A science course is a course in which more than one project can be used. In addition, it is a project-oriented course because it is related to real life in terms of its subject. It is inevitable to use the PBL approach in this course, in document the theoretical knowledge transferred to the student is associated with real life, and activities are carried out to improve the creativity of the student. Science knowledge can be obtained by experimenting and observing. For this reason, the PBL approach has been emphasized in the education system in recent years. However, it is seen that there are not many applications that support PBL in the field of science and studies that evaluate such applications (Dori & Tal, 2000; Solomon, 2003; Thomas, 2000).

One of the most important indicators of the development of a country's education system is scientific research in the field of education. It is the fastest and most accurate way to share and transfer scientific research results with other researchers in scientific journals. (Arık & Türkmen, 2009).

New researchers gain knowledge about previous studies through published articles and studies (Henson, 2001; Tsai & Wen, 2005). Namely, organizing and examining the studies on science education at certain times and determining the trends are important in terms of helping people who want to work on this subject (Çiltaş et al., 2012). For this reason, content analysis of the studies should be done (Gül & Köse, 2018).

In the pool where many related or unrelated studies are included, the evaluation of the studies and the creation of a general table are provided with the content analysis method. At the same time, content analysis studies in a field such as science education are a valuable resource that should be consulted and useful for future researchers in this field in terms of summarizing published studies under certain categories with a holistic approach. For this reason, thanks to the content analysis of the studies, the people working in the field of science education will have knowledge of the trends in both national and international literature, will avoid re-examining the previously and continuously studied topics, and will thus benefit the literature by making new and original studies (Çalık et al., 2008).

Bibliometric analysis is an approach that uses quantitative methods to monitor, measure, monitor and analyze scientific literature (Roemer & Borchardt, 2015). Bibliometric research is based on analyzing certain features of publications or documents and obtaining data related to the scientific side of communication (Al & Coştur, 2007; Yılmaz, 2017).

When the literature is examined, bibliometric analysis has been applied by many researchers from different disciplines to detect trends in research (Azer, 2017; Çelik et al., 2021; Çetinkaya & Çetin, 2016; Karagöz & Ardıç, 2019; Kulak, 2018; Kulak & Çetinkaya, 2018; Kumar et al., 2021; Moral-Muñoz et al., 2020; Polat et al., 2013; Zhang et al., 2022). However, no research has been found that makes a bibliometric analysis of project-based learning in science education. Therefore, this study is very important for a researcher who wants to do project-based learning in the field of science education to have information about the research.

The aim of this study is to make bibliometric analyzes of project-based learning studies in science education within the framework of various parameters. In the research process, answers were sought to the following questions:

1) What is the distribution of studies on project-based learning in science education between 1994-2023 by years?

2) What is the distribution of studies on project-based learning in science education between 1994-2023 according to keywords?

3) What is the distribution of studies on project-based learning in science education between 1994-2023 by terms?

4) What is the distribution of studies on project-based learning in science education between 1994-2023 by country?

5) What is the distribution of studies on project-based learning in science education between 1994-2023 according to the authors?

6) What is the distribution of studies on project-based learning in science education between 1994-2023 according to the sources?

METHOD

Scopus database was used to access studies on project-based learning theory in science education. The data of the research were collected on January 5, 2023.Scopus is an abstract and indexing database with full-text links that is produced by Elsevier Co. (Burnham, 2006). Scopus is accepted as the most comprehensive and bibliographic resource (Çelik et al., 2021; Kulak et al., 2019). The reason why Scopus database is used instead of Web of Science or Google Scholar for bibliometric analysis is that the Scopus database is the largest database in the literature, produces information with better decisions and results, and is a valuable resource for bibliometric studies. It is preferred more because it provides an inclusive and broad perspective in social sciences and other fields (Ekinci & Özsaatçi, 2023; Işın, 2022; Martín et al., 2018).

In order to determine the studies to be included in the study, some screening and selection criteria were determined by the researchers. First of all, “Article title, Abstract, Keywords” section was selected in order to get the most results from the search within search button in the Scopus database. Then, the search was carried out by typing "science education and project-based learning" in the section of the Scopus where the "search documents" search button is located. As a result, 1676 documents on "science education and project-based learning" were discovered. Then, the Social Sciences section of Scopus was selected and filtered, and as a result, 885 publications were included in the research. The reason for filtering is that not all of the accessed publications are related to the subject, so the Social Sciences section has been selected. 885 publications constitute 414 journal articles, 389 conference papers, 39 book chapters, 17 reviews, 16 conference reviews, 8 books, 1 editorial and 1 note. The years of accessed publications are between 1994 and 2023. No language restrictions are taken into account. In the search section, this search method was preferred as the reason for searching Scopus in this way is to reach the most publications on the subject. Therefore, the limitation of this study can be said that the search method in the research was "science education and project-based learning". The publications were then exported to CSV form and in turn subjected to the bibliometric analysis using VOSviewer (Visualization of Similarities) Software.

Analysis of Data

Bibliometric analysis has gained big popularity in research in recent years (Donthu, Kumar & Pattnaik, 2020; Donthu, Kumar, Mukherjee et al., 2021; Donthu et al., 2021). Bibliometric is an R statistical package for analyzing and visualizing the bibliographic data from WoS and Scopus databases (Derviş, 2019). By systematically examining the research carried out from the past to the present, valuable information such as the development of that subject, which main elements have been focused on overtime, which areas have not been examined yet, the similarities and differences of the researchers' findings. One of the ways to achieve these benefits is a bibliometric analysis (Ukşul, 2016). Bibliometric is the study of quantitative analysis of scientific interaction and comparisons by analyzing the characteristics of various publications such as books, articles, and documents, such as author, publication information, and the number of citations (Al, 2008, p.18-19). In order to summarize the temporal and holistic plane that is not easily understood due to the ever-increasing development of science education literature, the bibliometric network analysis method was preferred in this study. Another reason we prefer this method is to visualize scientific research with this method and to determine the relationships between certain topics, authors, journals, countries or institutions (Van Eck & Waltman, 2010: 523-538). VOSviewer is known as a software tool that creates and visualizes bibliometric networks (Van Eck & Waltman, 2017). The program is used to create maps of publications, authors, or journals based on a citation, co-citation, or bibliographic link network, or to create keyword maps based on a co-occurrence network (Van Eck & Waltman, 2011).

In this research, VOSviewer v.1.61 program was used. In addition, the bibliometrix program was used for Lotka's law and author effect ratio in the study. Bibliometrix is an R statistical package for analyzing and visualizing the bibliographic data from WoS and Scopus databases (Derviş, 2019).

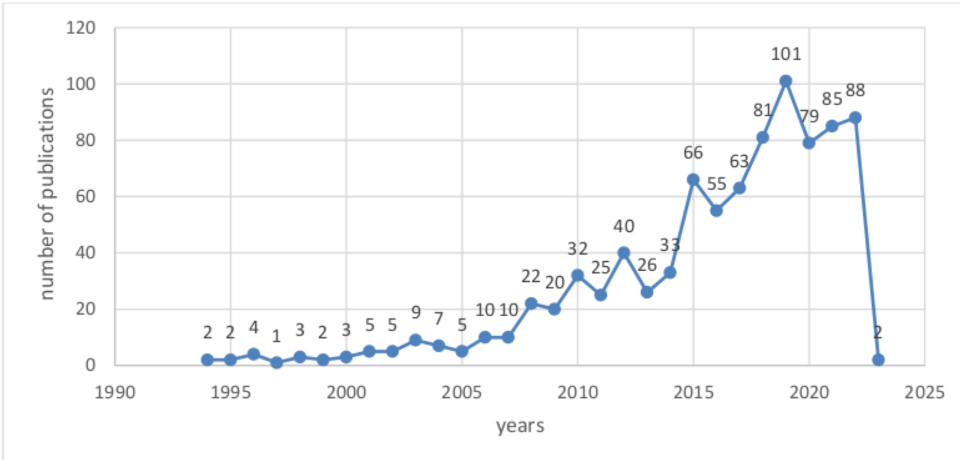
FINDINGS

Distribution of Publications by Years

When the trend of 885 publications in science education is examined in Figure 1; it is seen that studies on the subject started in 1994. It is seen that the year in which the most studies were published was 2019 with 101 studies. Although there are increases and decreases in the number of studies between 1994-2023, the number of studies generally increases. It is thought that the increase in studies on project-based learning in science education is due to the fact that project-based learning is considered important for scientists.

Figure 1

Number of Documents Published Between Years



Most Used Keywords in Publications

The keyword is the critical point of research. In this context, core keywords were revealed by performing keyword analysis. Threshold value shows at least how many times a reference is repeated (Akpınar & Atak, 2017). Figures for threshold values can take different forms in different datasets. When the threshold value is increased, the number of keywords to be included in the analysis decreases. When the threshold value is lowered, the number of keywords to be included in the analysis increases (Öztürk & Gürler, 2021). A maximum of 100 keywords were requested by the researchers to be included in the research. Therefore, the threshold value meeting this selection criterion was determined as 5 and preferred. Out of the 2240 keywords, 81 met the threshold. If this threshold value is set to 6, the number of keywords to be included in the analysis decreases to 65. Therefore, the threshold value was set as 5 in order to include more keywords in the analysis (Table 1). The image created with Vosviewer for keyword analysis is given in Figure 2.

Table 1

Examining the Publications in Terms of Keywords

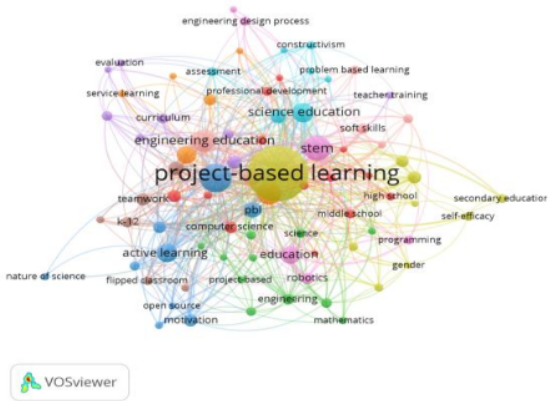
Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
project-based learning	291	359	professional development	8	14

project based learning	77	82	self-efficacy	8	9
stem	61	105	teacher education	8	10
stem education	47	81	collaboration	7	18
engineering education	46	73	constructivism	7	15
science education	39	54	design-based learning	7	13
active learning	35	59	educational technology	7	17
computer science education	33	48	flipped classroom	7	16
education	31	57	high school	7	16
higher education	28	52	online learning	7	16
PBL	23	32	arduino	6	17
creativity	19	29	curriculum development	6	10
problem-based learning	19	42	evaluation	6	9
collaborative learning	17	28	mathematics	6	11
project-based learning (PBL)	16	22	nature of science	6	4
steam	16	36	problem-solving	6	12
teamwork	16	32	project	6	4
motivation	15	28	project management	6	15
computational thinking	14	20	project-based	6	13
computer science	14	24	service learning	6	8
engineering design	14	19	steam education	6	9
experiential learning	14	35	teacher training	6	7
robotics	14	37	ınnovation	6	10
engineering	12	32	ınterdisciplinary education	6	10
k-12	11	21	community	5	5
soft skills	11	23	covıd-19	5	13
curriculum	10	17	critical thinking	5	7
curriculum design	10	21	e-learning	5	12
technology	10	24	elementary education	5	7
assessment	9	14	engineering teaching kits	5	7
mathematics education	9	20	equity	5	11
pedagogy	9	19	gender	5	14

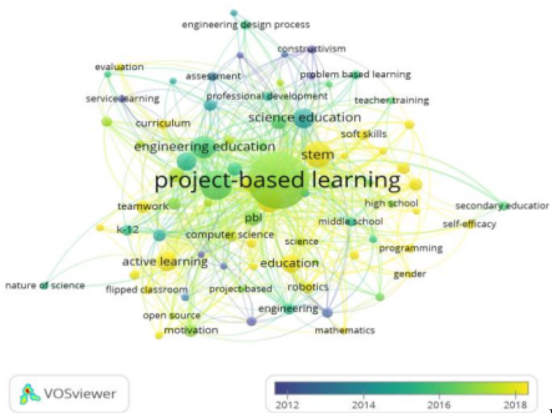
programming	9	23	k-12 engineering education	5	8
science	9	16	learning environment	5	11
secondary education	9	11	multidisciplinary	5	11
software engineering	9	16	open source	5	18
engineering design process	8	14	sustainability education	5	10
game-based learning	8	18	teacher professional development	5	4
learning	8	11	teaching methods	5	10
middle school	8	23	technology integration	5	10
problem based learning	8	10			

Figure 2

Keyword Network Analysis (A) and Temporal Trend of These Clusters (B)



A



B

When Figure 2 was evaluated in the context of cluster formation, 10 clusters were determined. 6 clusters related to the subject draw attention. These are indicated by the color yellow, blue, red, green, turquoise, pink.

The prominent term in the yellow cluster is “project-based learning” (359 total link strength, 74 links). This finding is not surprising at all, as project-based learning studies were examined in this study. This term is followed by keywords such as "steam," "collaboration", "computational thinking", "design-based learning.

The red cluster includes keywords "community", "computer science", "covid 19", "e-learning", "educational technology", "equity", "high school", "innovation", "middle school", "online learning", "professional development", "project-based learning" and "teacher education". The strongest node of the red cluster is the “computer science” keyword (24 total link strength, 18 links). Pucher & Lehner (2011) stated that most teachers agree that teaching with project-based learning has many advantages in computer science.

“Project-based learning” is the prominent keyword in the blue cluster (82 total link strength, 45 links). In the same cluster, after "Project-based learning", the keywords "active learning", "experiential learning", "PBL", and "motivation" draw attention.

"Engineering" stands out as the strongest node in the green cluster (32 total link strength, 24 links). Özyurt & Özyurt (2017) stated that the project-based learning approach has an important place in the professional development of engineering candidates in the context of engineering education. After “Engineering”, the terms “Technology”, and “mathematics education” stand out.

"Science education" stands out as the strongest node in the turquoise cluster. (54 total link strength, 27 links). Since we examined the studies on project-based learning in science education, it is not surprising that the keyword science education came up. This term is followed by the keyword “problem-based learning”. The reason for this is that project-based learning improves students' problem-solving skills and problem-based learning skills (Vatansever Bayraktar, 2015).

“STEM” is the featured keyword in the pink cluster (125 total link strength, 46 links). Regarding this issue, Breiner et al. (2012) stated that in STEM education practices, research-based and project-based learning methods are used, based on daily life examples, instead of traditional learning methods. This word is followed by the keyword “education”. Pesta et al. (2018) emphasized in their study that the keyword "education" may attract relatively more research interest due to its multidisciplinary nature.

According to the time trend, which is the second dimension of the analysis, in recent studies on project-based learning in science education, "STEM", "STEM education", "active learning", "education" etc. It is seen that words are mentioned (Figure 2-B). This finding can be considered as an indicator of new research interests of academics. In recent studies, it is seen that the STEM education approach is associated with project-based learning (Akarsu et al., 2020; Altan, 2017; Çakır & Ozan, 2018; Çevik, 2018).

Learning methods and techniques are very important in science education. As a matter of fact, Project-based learning is one of the active learning methods in which many problems and events encountered in real life are investigated and the results are expressed (Maulana et al., 2019).

Most Used Terms in Publications

18634 terms have been used in science education studies for project-based learning. In the research, 20 documents were taken into account as the minimum number of passages of a term. Of the 18634 terms, 240 met the relevant threshold. A relevance score was calculated for each of the 240 terms. Accordingly, the most relevant terms were selected. The default choice was to choose the most relevant terms 60% of the time. Finally, 144 terms were selected for further analysis of the visualization and networks between terms. Table 2 gives the distribution of terms used in publications on science education and project-based learning.

Table 2

Examining the Publications in Terms of Terms

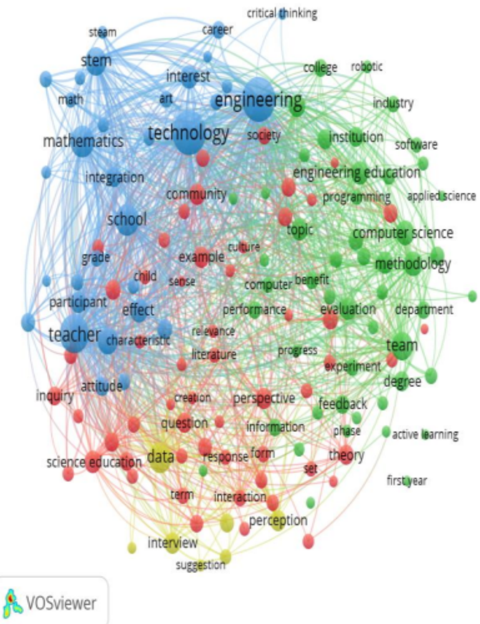
Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
technology	330	0.4323	end	44	0.5479
engineering	324	0.4939	laboratory	44	0.542
teacher	245	0.6681	reflection	44	0.7712
mathematics	164	13.838	country	43	0.4581
school	163	0.2904	high school student	43	16.518
data	157	0.4872	lesson	43	10.137
stem	139	1.959	observation	43	11.992
team	138	0.5697	response	43	0.5774
classroom	123	0.3605	review	43	0.4475
methodology	106	0.8925	state	43	0.6936
computer science	101	11.473	achievement	42	10.092
engineering education	96	11.035	math	41	17.913
effect	93	0.386	person	41	0.9625
interest	91	0.7071	programming	41	0.9274
hand	86	0.428	technique	41	0.6588
science education	86	14.066	unit	41	26.431
topic	86	0.4238	literature	40	0.6556
order	85	0.606	software	40	16.737
evaluation	81	0.4973	computer	39	0.6184
participant	80	0.6317	nature	39	11.057
perception	77	0.4454	contribution	38	12.357
community	75	0.339	detail	38	0.566
example	74	0.5266	learning process	38	0.8235
interview	74	10.363	set	38	0.6868
perspective	74	0.615	theme	38	0.7079
effectiveness	72	0.4162	view	38	12.295
question	69	0.4183	demand	37	0.5685
degree	68	0.9691	investigation	37	11.247
higher education	67	0.8174	gap	36	0.4107
theory	67	0.5732	instructor	36	0.7134
faculty	66	10.157	child	34	0.5839
institution	66	0.927	game	34	0.578
integration	66	0.5403	graduate	34	26.619
communication	65	0.6625	insight	34	0.5323
educator	65	0.3204	chapter	33	1.499
innovation	64	0.531	characteristic	33	0.6613
learner	64	0.8084	high school	33	18.818

instruction	63	14.358	lecture	33	11.512
engineering student	62	14.689	culture	32	0.8392
feedback	62	0.7765	phase	32	0.6315
engineer	61	12.719	robotic	32	21.952
researcher	61	0.6378	place	31	0.9167
world	61	0.7134	professional development	31	17.378
engagement	60	0.7636	progress	31	0.6405
inquiry	60	14.228	creation	30	11.905
questionnaire	60	0.819	week	30	0.517
attitude	59	0.6286	relevance	29	0.7886
career	57	11.887	series	29	0.7267
performance	57	0.6181	steam	29	28.954
society	57	0.8819	sustainability	29	15.252
experiment	56	0.5145	attention	28	0.5704
idea	56	0.9997	future	28	0.9638
implication	56	0.7721	academic year	27	15.529
information	56	0.4385	collaborative learning	27	0.4685
competency	55	0.8575	real world problem	27	0.7232
initiative	54	0.26	today	27	11.234
benefit	53	0.5495	combination	26	0.5346
college	51	11.668	difficulty	26	0.5457
department	51	14.658	engineering design	26	0.9367
creativity	50	0.4857	student learning	26	1.243
evidence	50	0.8908	variety	26	0.4754
industry	50	20.504	sample	25	15.339
relationship	50	0.5546	advantage	24	0.9958
teamwork	50	14.527	suggestion	24	11.426
difference	49	0.5529	critical thinking	23	15.055
interaction	48	0.506	soft skill	23	36.389
semester	48	15.784	applied science	22	3.858
term	48	0.7806	complexity	22	16.006
grade	47	0.832	sense	22	0.7885
form	46	0.5851	active learning	21	33.436
stem education	46	27.607	social science	21	1.662
art	45	10.747	first year	20	3.032

Accordingly, the most frequently used word in this study was determined as "technology" (f=330). This is followed by the terms “Engineering” (f=324) and “teacher” (f=245). When evaluated in terms of affinity relationship, it was determined that the term "engineering student" (R. Sc: 14.689) had the highest relevance score. This is followed by the terms “instruction” (R. Sc: 14.358) and “science education” (R. Sc: 14.066) (Table.2). In term analysis, 4 clusters were identified (Figure 3-A). Cluster-1 (red) consists of 55 terms. The most prominent are the terms “science education”, “community”, “example”. Cluster-2 (green) consists of 50 terms, most notably the terms “team”, “computer science”, “topic”, “communication”. Cluster-3 (blue) consists of 32 terms, most notably the terms "technology", “engineering”, “teacher”, “mathematics”. Cluster-4 (yellow) consists of 7 terms. The most prominent are the terms “data”, “interview”, “perception”. Also, in Figure 3-time trend analysis, the yellow color shows the recently preferred terms.

Figure 3

Term Analysis (A) and Temporal Trend of These Clusters (B)



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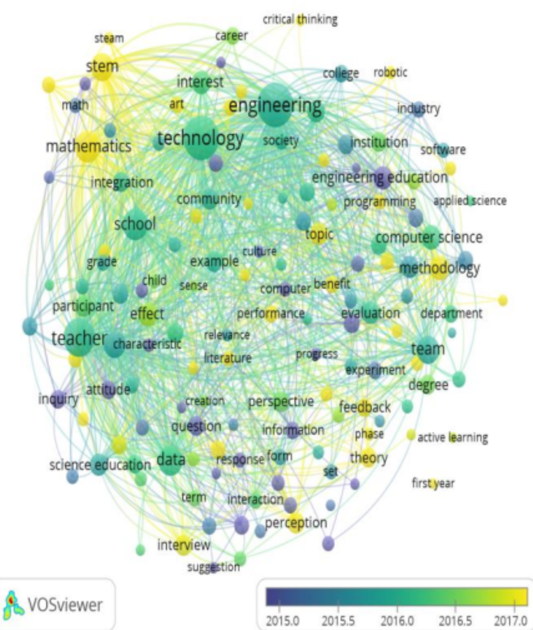


B

Top Broadcasting Countries

A country analysis was also conducted to reveal the spatial distribution of reports. In Table 3, the distribution of publications related to science education and project-based learning according to the countries where they are produced is given. 84 countries have conducted studies on project-based learning with science education. In this research, countries with at least 5 studies on the subject were selected and a total of 36 countries were analyzed.

Table 3

Examining the Publications in Terms of Countries

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
United States	320	4089	43	France	12	77	6
Spain	69	935	16	Russian Federation	12	58	0
United Kingdom	35	119	12	Italy	12	172	5
China	32	179	7	Hong Kong	11	76	3
Germany	31	302	7	Norway	10	32	3
Taiwan	30	1072	3	Romania	10	29	12
Australia	24	274	6	Austria	9	40	3
Turkey	24	266	4	Belgium	9	23	4
Finland	22	134	4	Colombia	9	66	5
India	22	100	7	South Korea	9	158	6
Malaysia	20	200	5	Chile	8	83	5
Portugal	20	105	7	Greece	8	30	3
Brazil	18	93	7	Netherlands	8	181	6
Israel	18	353	3	Singapore	8	32	4
Canada	16	250	6	Sweden	7	16	8
Indonesia	16	92	3	Mexico	6	11	3
Denmark	15	255	7	Peru	5	33	1
Japan	13	47	1	South Africa	5	5	1

Figure 4

The Nexus of Citation Among the Countries (A) and Temporal Trend of These Clusters (B)

A

B

It has been determined that "USA" has more important nodes with 4089 citations. This country is followed by "Taiwan" with 1072 citations, "Spain" with 935 citations, and "Israel" with 353 citations. In this study, the country where the study was produced with 320 publications between 1994-2023 was determined as "USA". This finding supports the view that the country is one of the leading countries in the field of science education (Demir & Selvi, 2018; Yurdakul & Bozdogan, 2022). In this analysis, 9 clusters with high citation relations were identified. The first cluster (red) includes China, Finland, Greece, Hong Kong, Netherlands, Singapore, United Kingdom. The closest cluster to which the first cluster group refers most is the fourth cluster represented by yellow circles. The fourth cluster includes Israel, Norway, Turkey, United States. It is seen that the United States is the focus of the yellow cluster. Cluster 2 (green) Indonesia, Italy, Malaysia, South Africa, South Korea, Taiwan; cluster3 (blue) Australia, Austria, Peru, Spain; Cluster 5 (magenta), Belgium, Denmark, Romania, Sweden; Cluster 6 (turquoise) Canada, Colombia, France, India; Cluster 7 (orange) Chile, Germany, Mexico; Cluster 8 (burgundy) Brazil, Japan, Portugal; Cluster 9 (purple) contains the Russian Federation (Figure 4-A). The most important result obtained in the time trend analysis is the identification of Indonesia, Portugal, South Africa as new citation foci. (Figure 4-B)

Most Productive Authors in the Documents

In this research, a total of 2433 authors have worked on the subject. In order to reveal the relationship between the authors with a clear analysis, 49 authors with at least three publications were included in the analysis.

Table 4

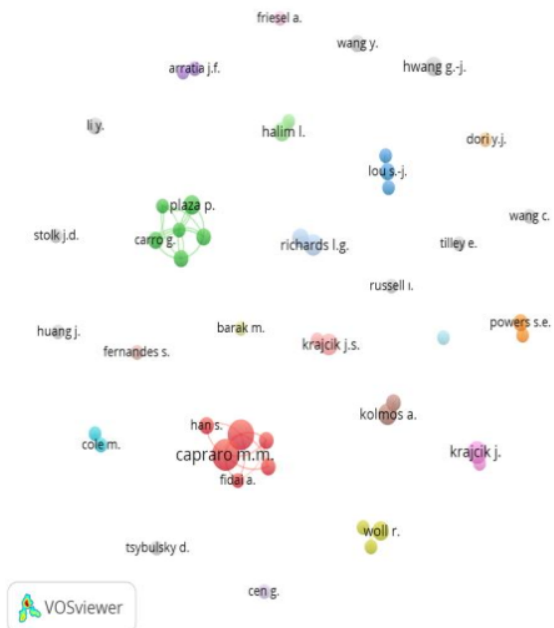
Examination of Publications in Terms of Authors

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Capraro M.M.	13	377	26	Bojic I.	3	8	3
Capraro R.M.	12	157	25	Cen G.	3	1	0
Krajcik J.	7	280	2	Chang C.-C.	3	243	1
Kolmos A.	6	219	3	Chung C.-C.	3	27	3
Krajcik J.S.	6	608	3	Cole M.	3	24	3
Richards L.G.	6	56	5	Dewaters J.E.	3	27	3
Donohue S.K.	5	12	5	Domènech-Casal J.	3	15	0
Halim L.	5	67	3	Dori Y.J.	3	80	0
Hwang G.-J.	5	244	0	Fernandes S.	3	1	0
Plaza P.	5	43	18	Fidai A.	3	12	7
Woll R.	5	21	6	Friesel A.	3	7	0
Barroso L.R.	4	31	12	Garcia-Loro F.	3	26	14
Bicer A.	4	34	11	Huang J.	3	27	0
Carro G.	4	40	18	Kazula S.	3	12	5
Castro M.	4	40	18	Marx R.W.	3	450	3
Han S.	4	339	5	Osman K.	3	60	3
Holgaard J.E.	4	45	3	Rich B.M.	3	10	5
Li Y.	4	50	0	Russell I.	3	11	0
Lou S.-J.	4	252	4	Severance S.	3	26	2
Powers S.E.	4	41	3	Stolk J.D.	3	29	0
Sancristobal E.	4	40	18	Tilley E.	3	3	0

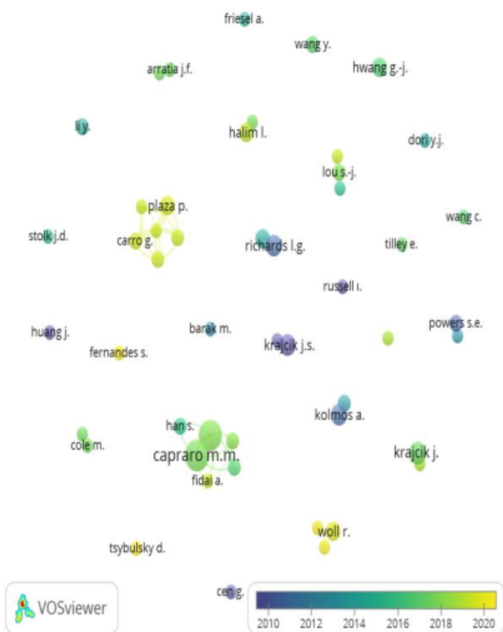
Wang Y.	4	18	0	Tsybulsky D.	3	50	0
Arratia J.F.	3	8	3	Wang C.	3	16	0
Barak M.	3	87	0	Wilhelm J.	3	24	3
Blazquez M.	3	24	14				

Figure 5

The Most Cited Authors (Co-Citation Analysis) (A) and Temporal Trend of These Clusters (B)



A



B

The most productive author found in this study is Capraro M.M. affiliated with the University of Texas A&M. She has 13 publications. The second-ranked goes to Capraro R.M., affiliated with the University of Texas A&M with 12 academic works. In the research, Krajcik J.S. He is the most cited author with 6 publications. Also, Marx R.W is noteworthy that 3 publications and 450 citations were cited. The reason for this can be shown to be that they broadcasted in earlier years. As a matter of fact, when the author's impact rate is examined, it is seen that Capraro M.M. started working on this subject in 2015. (Table 5). Figure 5-A shows the co-authorship network. In the time analysis image, which is the second dimension of the analysis, the yellow color shows the authors who have recently collaborated and published (Figure 5-B).

The productivity of the authors was also examined in terms of Lotka's law, which is widely used in bibliometric analyses. Lotka's law describes the frequency of publication by authors in a given field. It states that "the number (of authors) making n contributions is about $1/n^2$ of those making one; and the proportion of all contributors that make a single contribution is in the region of 60 percent" (Lotka, 1926; Potter, 1988; Rowlands, 2005). "The number of people who have two studies is about 1/4 of those who have one; the number of people who have three studies is 1/9 of those who have one; the number of people who have n studies is about 1/n of those who have one" and the rate of those who have a job among the working owners is about 60%. It is a measurement method that argues that 15% of the authors who publish in a journal will contribute with 2 publications, 7% with 3 publications and 3.75% with 4 publications (Lotka, 1926; cited by Yılmaz, 2006, p.63).in this study, authors' 92% (2260 authors) wrote one publication, 5% (141authors) two publications, 1% (28 authors) three publications and %004 (11 authors) wrote four publications. According to the findings, it has been determined that the author's distribution of the publications written does not comply with this law. Lotka's law and the rate of working authors were created by the authors through the R bibliometric program (Figure 6). In addition, the impact rate of the most productive authors on this topic is given through the bibliometric program (Table 5). Table 5 shows the total number of citations of the authors (TC), the number of publications they have made (NP), and when they started their first publication (PY).

Figure 6

Lotka's Law and The Rate of Authors

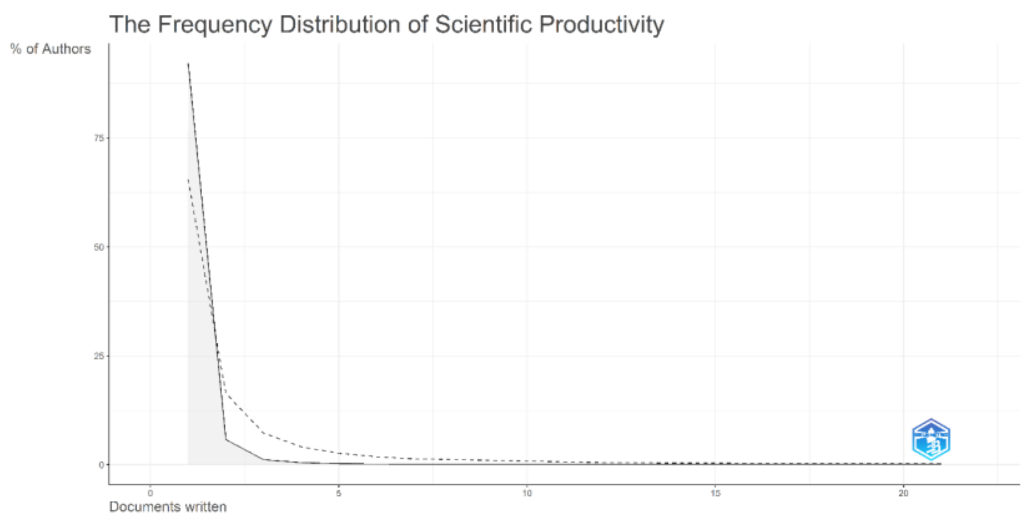


Table 5

Author Local Impact

Authors	h_index	g_index	m_index	TC	NP	PY_start
CAPRAROM M.	6	13	0,667	377	13	2015
KOLMOS A.	6	6	0,353	219	6	2007
KRAJCIK JS.	6	6	0,214	608	6	1996
CAPRARO RM.	5	12	0,556	157	12	2015
BICER A.	4	4	0,444	34	4	2015
HALIM L.	4	5	0,5	67	5	2016
HAN S.	4	4	0,444	339	4	2015
HWANG G-J.	4	5	0,333	244	5	2012
KRAJCIK J.	4	7	0,25	280	7	2008
LOU S-J.	4	4	0,364	252	4	2013

Examination of Publications in Terms of Source

In this research, a total of 409 resource studies on the subject were published. In order to identify the most preferred sources in the research, 31 sources with at least 5 publications were included in the analysis (Table 6). Accordingly, "Journal of Research in Science Teaching (9 documents, 631 citations), "Computers and Education" (6 documents, 618 citations), "International Journal of Technology and Design Education" (12 documents, 593 citations), were the most cited sources. It has been determined that "Proceedings - Frontiers in Education Conference, fie" (78 documents), "IEE Global Engineering Education Conference, Educon" (30 documents) are the sources with the most publications (Table 6).

Table 6

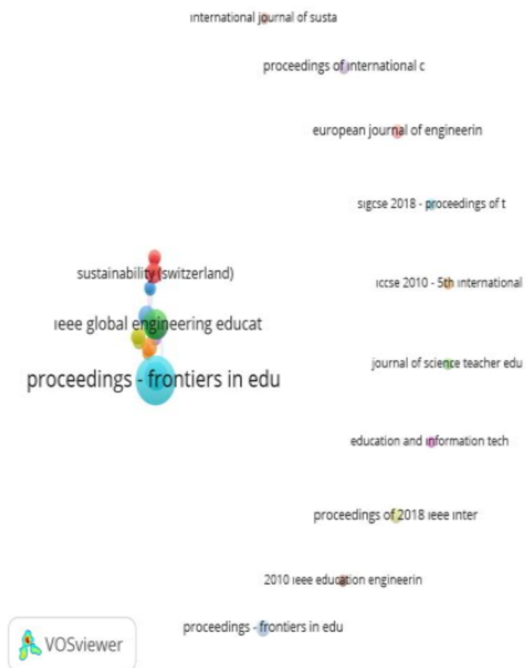
Most Popular Sources in the Documents

Source	Documents	Citations	Total Link Strength
Proceedings - Frontiers in Education Conference, Fie	78	267	1
IEEE Global Engineering Education Conference, Educon	30	132	3
International Journal of Engineering Education	27	368	6
IEEE Transactions on Education	16	497	8
Journal of Science Education and Technology	14	146	4
Sustainability (Switzerland)	14	258	4
International Symposium on Project Approaches in Engineering Education	13	14	3
International Journal of Technology and Design Education	12	593	10
Proceedings - Frontiers in Education Conference	10	104	0
Journal of Research in Science Teaching	9	631	4

Proceedings of the 40th Sefı Annual Conference 2012 - Engineering Education 2020: Meet the Future	9	14	1
Computer Applications in Engineering Education	8	97	1
Eurasia Journal of Mathematics, Science and Technology Education	8	213	2
Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, Tale 2018	8	39	0
Annual Conference on Innovation and Technology in Computer Science Education, Iticse	7	24	1
Education Sciences	7	30	3
European Journal of Engineering Education	7	110	0
Proceedings of International Conference of The Learning Sciences, Icls	7	20	0
Revista Eureka	7	23	1
Advances in Engineering Education	6	19	1
Computers and Education	6	618	3
Journal of Engineering Education Transformations	6	16	2
Journal of Geoscience Education	6	30	1
2010 IEEE Education Engineering Conference, Educon 2010	5	19	0
Education and Information Technologies	5	37	0
Education for Chemical Engineers	5	38	1
Journal of Science Teacher Education	5	23	0
Sıgcse 2018 - Proceedings of the 49th Acm Technical Symposium on Computer Science Education	5	64	0
ICCSE 2010 - 5th International Conference Sourcon Computer Science and Education, Final Program and Book of Abstracts	5	27	0
International Journal of Mechanical Engineering Education	5	29	2
International Journal of Sustainability İn Higher Education	5	95	0

Figure 7

The Most Cited Sources Clusters (Co-Citation Analysis) (A) and Temporal Trend of These Clusters (B)


international journal of susta
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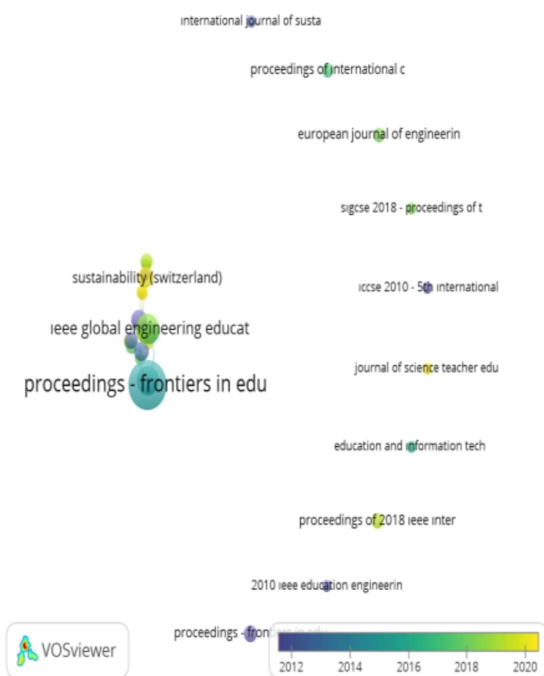
international journal of susta
proceedings of international c
european journal of engineerin
sigcse 2018 - proceedings of t
sustainability (switzerland)
iccse 2010 - 5th international
ieee global engineering educat
journal of science teacher edu
proceedings - frontiers in edu
education and information tech
proceedings of 2018 ieee inter
2010 ieee education engineerin
VOSviewer
2012
2014
2016
2018
2020

B

The most cited sources are visualized in Figure 7. A total of 17 clusters were identified. According to the time trend analysis, which is the second dimension of the analysis, "Educational Sciences", "Sustainability (Switzerland)", "International Journal of Mechanical Engineering" are preferred by researchers recently (Figure 7B). Some clusters have connections around them, a node can have many connections to other nodes, allowing it to be centrally located in the cluster. When the social network is examined, it is seen that relations are mostly knotted through publications such as "Proceedings - Frontiers in Education Conference, FIE" and "Sustainability (Switzerland)". This shows that these resources have a very important position in the network.

CONCLUSION

In this study, studies on project-based learning in science education are included. Bibliometric analyzes of the published studies were made using various parameters such as keywords, terms, authors, and countries. The results obtained from the research are as follows; The year in which the most studies were published between the years 1994-2023, which was determined as the time interval in the study, is seen as 2019. The most frequently used keywords in publications are "project-based learning", "computer science", "engineering", "science education", "STEM"; the most frequently used terms are "engineering student"; "instructions"; "science education". Another result of the research is that Capraro M.M, who has 13 publications on the subject, is the most prolific author. In addition, Lotka's law was used to measure the productivity of the authors, but it was found that it did not comply with this research. Accordingly, "Journal of Research in Science Teaching, "Computers and Education", "International Journal of Technology and Design Education" were the most cited sources in the studies.

RECOMMENDATIONS

This is the first study providing a bibliometric analysis of research trends in documents on the effects of science education and project-based learning between 1994 and 2023. This situation creates a unique field for new studies on the subject. This study provides an overview of and an effective understanding of the current status of the literature on project-based learning in science education and offers interesting insights into the development of the field. We believe that the results of this study are important for the future developments of project-based learning in the science education. Although the research is a study on project-based learning in particular, it is generally related to science education as a research area. Therefore, it gives ideas about how the issue can be handled in related disciplines. In addition, ideas about how and which studies can be conducted in other fields can be obtained from this study. From this point of view, science education researches will fill the gaps in the literature and provide the opportunity to follow new trends closely. Also, more detailed bibliometric studies can be conducted in different fields of education, taking into account the macro data presented in this research. Bibliometric studies are important for researchers to closely follow the studies and developments in that field. The research is also to include a method applicable to different fields of science. For this reason, it directs new researches' interests as a method how to follow and it may be recommended to conduct bibliometric studies in different fields.

In addition, moving from the findings of the present study, some suggestions could be made for further research in the field:

1- It is suggested that research on giving importance to identifying project-based learning must be continued.

2- According to the keyword analysis, the most relevant keywords are project-based learning", "computer science", "engineering", "science education", "STEM". Studies containing other keywords should be emphasized project-based learning.

3- According to the more common term analyses, the most relevant terms are "engineering student"; "instruction"; "science education". Studies containing other variables should be emphasized about project-based learning.

4- Scopus database was used in this study. Different databases can be used in future studies.

5- Different limitations can be used when searching for documents in future studies.

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