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Conceptual framework, methodology, data collecting, implementation and data analysis, organization of findings

Conceptual framework, literature review, organization of findings and writing the discussion and conclusion

Abstract

The aim of the study is to examine Problem Based Learning (PBL) studies in terms of descriptive and semantic content analysis by using topic modeling. For this purpose, descriptive and topic modeling analyzes were used together in the research. In order to include the highest number of articles on Scopus, the term "problem based learning" was searched in the title, abstract and keywords and only journal articles (research and review) were selected. Thus, 7289 articles in 1987-2021 were included in the study. Firstly, the subject area, author and country distributions are listed. In addition, it showed that the most studied topics were education curriculum (39.15%), teaching strategies (14.90%), critical thinking skill (12.29%) and patient simulation (8.88%). When examined in seven five-year periods between 1987 and 2021, it was determined that the most voluminous topic was education curriculum, and the most accelerated topic was clinical education. Considering the number of publications in five-year periods, it was determined that the topics of critical thinking skills and teaching strategies accelerated more in the percentages calculated according to the topics. It is expected that the results obtained will be important reference points for the studies to be carried out in the field of PBL.

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Research Article

A Broad View of the Problem-Based Learning Field Based on Machine Learning: A Large-Scale Study Based on Topic Modeling*

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Abstract

The aim of the study is to examine Problem Based Learning (PBL) studies in terms of descriptive and semantic content analysis by using topic modeling. For this purpose, descriptive and topic modeling analyzes were used together in the research. In order to include the highest number of articles on Scopus, the term "problem based learning" was searched in the title, abstract and keywords and only journal articles (research and review) were selected. Thus, 7289 articles in 1987-2021 were included in the study. Firstly, the subject area, author and country distributions are listed. In addition, it showed that the most studied topics were education curriculum (39.15%), teaching strategies (14.90%), critical thinking skill (12.29%) and patient simulation (8.88%). When examined in seven five-year periods between 1987 and 2021, it was determined that the most voluminous topic was education curriculum, and the most accelerated topic was clinical education. Considering the number of publications in five-year periods, it was determined that the topics of critical thinking skills and teaching strategies accelerated more in the percentages calculated according to the topics. It is expected that the results obtained will be important reference points for the studies to be carried out in the field of PBL.

Keywords: : Problem based learning, latent dirichlet allocation, topic modeling, research trends

1. INTRODUCTION

With the change in the world of information, the speed in knowledge production has caused some concepts in the literature to be reconsidered. Today, beyond accumulating knowledge, individuals who discuss, question, identify the problems around them and develop solutions to these problems are needed. Trilling and Fadel (2009) explain this situation with the increasing information resources and the developments in the speed of access to these resources, so they state that the competencies that individuals should have need to be redefined. Voogt and Roblin (2012) stated in their research that self-management, cooperation, communication, Information and Communication Technologies (ICT) proficiency, social skills, creativity, critical thinking and problem solving skills are among the basic competencies of the 21st century. Among these competencies, problem solving skills come to the fore (Phungsuk, Viriyavejakul & Ratanaolarn, 2017). Problem solving skills are accepted among higher-order thinking skills (Lewis & Smith, 1993).

One of the approaches frequently used to make the students gain problem-solving skills is the PBL approach. Hmelo-Silver (2004) states that PBL is designed to provide students with guided experiences in learning by solving complex, real-world problems. According to Manalo and Chua

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(2020), PBL is an active learning methodology that encourages critical thinking. Dolmans and Gijbels (2013) define PBL as a student-centered learning approach. PBL has emerged as a medium to make applications more realistic in medical education in higher education (Barrows & Tamblyn, 1980). Later, the PBL approach was widely used in many fields in different disciplines. With the spread of internet-based applications, digital PBL has gained popularity recently (Chao et al., 2021).

There are many studies in the literature on PBL, which is used in many disciplines in both face-to-face and distance education environments. In this context, especially in recent years, many bibliometric studies or systematic reviews on PBL have contributed to the literature. However, as can be seen in the literature, systematic review studies are generally conducted with a small number of studies (Haymana & Dağhan, 2020; Yang, Lo, Xia, Wan & Sun, 2016). When examining some of the studies in this sense;

- Newman (2003) conducted a systematic review to examine the effect of PBL in his research and this research included 12 studies.
- Kong, Qin, Zhou, Mou and Gao (2014) examined the effect of the use of PBL on students' critical thinking in nursing education skills in their study and included 9 articles in their systematic review.
- Williams and Beattie's (2008) research on the use of PBL in clinical education included 5 articles.
- Jin and Bridges (2014) focused on instructional technologies in the use of PBL in health sciences within 28 articles in their study.
- Koh, Khoo, Wong and Koh (2008) conducted a systematic review of 13 articles, including the use of PBL in medical education.
- Polyzois, Claffey and Attheos (2010) examined the short and medium term effects of PBL use in health education in their study and included 13 qualitative studies.
- Wilder (2015) also examined the effect of PBL on academic achievement in secondary education and conducted a systematic review study with 13 articles.
- In the study conducted by Sayyah, Shirbandi, Saki-Malehi and Rahim (2017), the use of PBL in medical and nursing education was examined by including 21 articles in their research.
- Galvao, Silva, Neiva, Ribeiro and Pereira (2014) examined the effect of PBL on student achievement in pharmacy education through 5 articles.

As can be seen from the studies, many systematic reviews have been conducted in the field of PBL. The fact that systematic reviews studies were generally conducted with a small number of articles or research does not mean that they do not contribute to the literature, but this can be considered as an important limitation (Gurcan, Cagiltay & Cagiltay, 2021; Ozyurt & Ozyurt, 2022). The processing of data by researchers in systematic review studies makes it difficult to carry out such studies on big data (Gurcan, Ozyurt & Cagiltay, 2021). Bibliometric studies can be considered as an alternative because they are conducted with big data. However, due to the fact that the studies examined in bibliometric analysis studies are carried out using only certain descriptive parameters, they provide very limited information in terms of the content of the studies (Gurcan et al., 2021). For example, Hallinger (2021) examined 14130 studies (articles, papers, reviews, etc.) between 1972 and 2019 in his bibliometric review and stated this as a limitation in the last part of his study that bibliometric reviews did not focus on the content of the studies. In this regard, topic modeling studies based on data-text mining can create an alternative solution. The themes and trends of the studies in the field examined in topic modeling studies can be handled on a very large scale (Gürcan & Özyurt, 2020; Gurcan et al., 2021). In recent years, it is seen that topic modeling studies have been preferred to overcome similar limitations. (Hu, Boyd-Graber, Satinoff & Smith, 2014; Ozyurt & Ozyurt, 2022). In terms of PBL field, it was stated that an important limitation was created in the number of studies examined in order

to achieve more generalizable results in many systematic review studies and this should be overcome (Azer & Azer, 2015; Jin & Bridges, 2014; Li, Wang, Zhu, Zhu & Sun, 2019; Yuan, Williams & Fan, 2008). In addition, some of the systematic review studies in the field of PBL are limited to certain databases such as databases in the field of medicine (Koh, Khoo, Wong & Koh, 2008). Based on all these, it is considered the study will make significant contributions to the literature as it has the potential to overcome a few important limitations in the literature in the field of PBL, new research is needed as PBL has started to find its place in distance education environments as well as in face-to-face education environments, and it is one of the most extensive and comprehensive studies in the literature in terms of scale. In this context, it was aimed to determine the interests and trends of research in the field of PBL by examining the studies on the PBL approach in terms of content and descriptive analysis by using the topic modeling analysis. For this purpose, answers to the following research questions were sought:

- What are the descriptive characteristics of the studies on the PBL?
  - RQ1. What is the distribution of PBL studies by years?
  - RQ2. What are the prominent subject areas in PBL studies?
  - RQ3. Which authors and countries stand out in PBL studies?
- What are the topics and what kind of changes have come out in the studies on the PBL?
  - RQ4. What are the prominent topics in PBL studies?
  - RQ5. How do the prominent topics in PBL studies change over time?

1.1. Literature Review

1.1.1. Problem based learning

PBL is a student-centered learning method and learning process that provides an organizational method for a course (Barrows & Kelson, 1993). The PBL approach exposes students to real-life problems (Savery, 2015). Students take an active part in the learning process while solving the problems they encounter. While discussing the problems they encounter, students can construct new knowledge based on what they know (Bransford & McCarrell, 1977). One of the modern learning approaches on which PBL is based is collaborative understanding. Shen, Wang, Yang and Yeh (2012) define PBL as a learning method in which the teacher presents a problem to the students and initially watches them work on their own, then they discuss possible solutions to the problem with group work and find the most appropriate solution.

While the PBL approach facilitates students' learning, it increases their motivation for the lesson (Hallinger & Lu, 2011). In addition, small group discussions improve students' problem-solving and higher-order thinking skills (Blumenfeld, Marx, Soloway & Krajcik, 1996). Thanks to this approach, students can increase their communication skills (Uden & Beaumont, 2006) and improve their critical thinking skills (Goodnough & Cashion, 2006). According to Hmelo-Silver (2004), PBL has advantages such as easier adaptation to changes, finding solutions to problems, critical and creative reasoning, collaborating with the group, identifying their own strengths and weaknesses, acquiring self-learning skills, being open-minded and encouraging active learning. Because, in traditional approaches, the role of the student, who acquires knowledge only by listening to the teacher, leaves its place to the role of the student who makes his knowledge permanent by researching, examining, experimenting and interacting with his environment. However, as with many learning approaches, PBL has some limitations. Compared to traditional approaches, the workload of both the teacher and the student increase in the PBL approach. In addition, some courses and curricula are not suitable for PBL (Nicholl & Lou, 2012).

In the PBL approach, the learning process is expected to encourage students to solve problems using active learning and higher-order thinking skills (Albanese & Mitchell, 1993; Jonassen, 2000). For this, scenarios are prepared in which students will encounter problems similar to those in real life. Scenarios are an important part of the PBL approach and these scenarios need to have some characteristics. Scenarios should not be well-structured, simple and understandable in a way that students can encounter in daily life (Hmelo-Silver, 2004). It is important to ensure that each scenario focuses on only one problem situation (Ram, 1999). There should be guiding tips for teachers and students in the prepared scenarios. Thus, it can be ensured that students evaluate their problem situations without moving away from their learning goals (Aksoy, 2011). The problem situation in the scenarios should be challenging, multi-directional and interesting for the student (Hmelo-Silver, 2004). Scenarios should be suitable for children's mental development, in a size that can be solved within the learning period, and should allow students to form hypotheses (Ram, 1999). Thus, students will be able to actively participate in the learning process.

In the PBL process, students need to be guided so that they can perform the problem solving process (Peterson, 2004). Teachers have important responsibilities during and after the PBL preparation process. In the PBL process, teachers are the individuals who facilitate learning, encourage students to think reflectively (Hmelo-Silver, 2004), organize activities and discussions (Hoffman, 1998), and are cognitive and metacognitive guides. Although it is thought that the real heroes of the process are the students, it is very difficult to manage the process without the guidance and direction of the teachers. In the PBL approach, students work collaboratively in small groups. It is very important in this approach to provide students with environments where they can structure their own learning by benefiting from each other's experiences (Taylar & Hamdy, 2013), enable students to acquire new information about the problem situation (Song, Grabowski, Koszalka, & Harkness, 2006). Carey and Whittaker (2002) stated that it is very important for a successful PBL process that students work as a member of a team and have the ability to collaborate with their peers. In the PBL process, students work in groups of 5-7 collaboratively to solve the problem. At this stage, it is very important that the groups are formed correctly because sloppy forming of groups can turn a positive learning experience into a negative one (Alfonseca, Carro, Martín, Ortigosa, & Paredes, 2006). Lei, Kuestermeyer, Bailey and Westmeyer (2010) identified at least six main factors to be taken into consideration when grouping students; gender, ethnicity, familiarity among members, ability, level of motivation and resources. According to Chan et al. (2010), on the other hand, stated that students' academic achievements should be taken into account while forming groups in a heterogeneous way. Random grouping (Chan et al., 2010; Huxland & Land, 2000), selection by teacher (Hilton & Phillips, 2010), and selection by students (Hilton & Phillips, 2010) are among the most commonly used methods for group formation.

1.1.2. Using ICT in problem based learning

PBL approaches require a change in the teacher-student relationship that emphasizes access to resources and student-centered approaches. At this point ICT can act as a lever for PBL (Lone Dirckinck-Holmfeld, 2009). In addition, ICT makes PBL practically applicable. In this context, PBL is considered as a suitable alternative for ICT integration (Pearson, 2006). As a matter of fact, the emphasis is on the fact that ICT can be used to solve real-world problems in the real learning process (Jimoyiannis, 2010). Similarly, Koehler and Mishra (2005), emphasizes that teachers consider the inclusion of ICT in collaborative authentic problem-solving tasks as an effective way of learning. Karami, Karami and Attaran (2013) states that some students, who are less interested in classroom activities, enjoy working with computers, and that they can play a more active role in the classroom thanks to this integration. In this context, many studies can be mentioned in the literature on the integration of ICT into PBL environments (Osman & Kaur, 2014; Virtanen & Rasi, 2017). The common consensus in these studies is that the integration of ICT into PBL can support and facilitate

learning by structuring students' real-world problems in a meaningful way (Donnelly, 2010; Fidan & Tuncel, 2019; Jin & Bridges, 2014). In the light of these studies, it can be said that the integration of ICT into PBL environments is important and necessary to enrich learning.

2. METHOD

2.1. Research Design

Descriptive analysis and topic modeling analysis were used in this research, which aims to examine the studies on the PBL approach in terms of descriptive and semantic content analysis. Descriptive analysis involves organizing, categorizing, and comparing texts and thus obtaining results from texts (Cohen, Lawrence & Morrison, 2017). With this analysis, the descriptive features of the field were revealed. Topic modeling analysis also aims to extract semantic patterns latent in large data sets (Blei, Ng & Jordan, 2003). In other words, topic modeling is an unsupervised machine learning method used to automatically discover latent semantic structures called "topics" in a certain whole (Blei, 2012; Gurcan & Cagiltay, 2019). Topic modeling, which is a probabilistic approach, is often preferred for discovering latent semantic patterns from large data piles that are difficult to handle and analyze (Blei, 2012; Gurcan et al., 2021). In this approach, textual documents contain latent semantic patterns called "topics". Latent Dirichlet Allocation (LDA) algorithm (Blei et al., 2003), which is a generative approach for probabilistic topic models, was used in the study. LDA is widely used in natural language processing, information extraction, job postings, literature research, and content analysis based on topic modeling (Blei & Lafferty, 2007; Gurcan, et al., 2021; Gurcan & Cagiltay, 2020; Ozyurt & Ozyurt, 2022; Ozyurt & Ayaz, 2022). In addition, the LDA algorithm provides an efficient method to calculate the consistency score for the estimation of the optimal number of topics and is therefore widely used for topic modeling (Blei, 2012; Gurcan et al., 2021; Gurcan & Cagiltay, 2019). In this context, LDA analysis was used in the study.

While conducting the research, data collection process, data preprocessing stages, topic modeling and reporting stages were carried out. These stages are presented sequentially in Figure 1.

Figure 1. Stages of the research

2.2. Data Collecting

One of the most critical stages in literature research-based topic modeling studies is the creation of the imperial corpus (Gurcan et al., 2021) because the creation of the corpus is important in terms of determining the scope of the field. In this context, the Scopus database was chosen to reach as many articles as possible. The Scopus database has been used to obtain articles relevant to the scope of the study as it covers more than 7000 publishers worldwide, including Elsevier, Emerald, IEEE, Sage, Springer, Taylor & Francis, and Wiley Blackwell, and this number is increasing day by day (Evia, Sharp & Perez-Quinones, 2015; Scopus, 2022). In order to include the highest number of articles on Scopus, the term "problem based learning" was searched in the title, abstract and keywords and only

journal articles (research and review) were selected. Finally, the year 2022 excluded from the search query, all journal articles published from the past to the present (as of the end of 2021) were selected. This selection has returned a total of 7317 articles on scopus from past to present (between 1974 and 2021). In the preliminary examination, it was seen that the total number of articles in 1974-1986 was 28, and its ratio in the total number of articles was below 0.5%. This situation was evaluated by the researchers and it was decided to exclude 28 articles before 1987. Based on these criteria, the following final query was created:

> TITLE ("problem based learning" OR "problem-based learning") OR ABS ("problem based learning" OR "problem-based learning") OR AUTHKEY ("problem based learning" OR "problem-based learning") AND PUBYEAR > 1986 AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (EXCLUDE (PUBYEAR , 2022))

This query was used to construct the empirical corpus of the research from the Scopus database. The query was run on June 1, 2022. The search returned a total of 7289 articles (6625 research and 664 review). The title, abstract, author and keywords of these articles were added to the data set.

2.3. Data Pre-processing Stages

The data pre-processing stage is an important sequence of operations that directly affects the success of the analysis in data/text mining (Aggarwal & Zhai, 2013; Gurcan & Cagiltay, 2020). With the sequence of these processes, raw data is converted into a clean dataset ready for analysis (Aggarwal & Zhai, 2013). In this empirical analysis, the following sequential steps were carried out in the preprocessing process in order to successfully apply the topic modeling process to the PBL corpus.

First, all textual content in the dataset was converted to lowercase, and web links, tags, publisher information, numeric expressions, punctuation and symbols in the dataset were cleaned. Then, word tokenization was applied to represent the textual contents as single words. Then, words and stop words (a, an, is, the, of, for, etc.) that do not make sense in the text were discarded. Similarly, generic words (e.g. literature, purpose, article, research, study, and copyright) that are frequently observed in articles but do not contribute to the establishment of semantically coherent topics are also added to the stop word list. Lemmatization was performed to reach the stem of the words. In this way, it is ensured that words derived from the same root are singular. Finally, each of the articles forming the corpus was converted into a word vector using the “word bag” approach to provide a numerical representation of the words in the corpus. At the end of all these processes, a document term matrix (DTM), which represents the whole corpus and provides the necessary matrix form for the topic modeling analysis, was created by combining these vectors (Blei et al., 2003; Gurcan et al., 2021). All these processes were carried out using Python language and data analysis libraries.

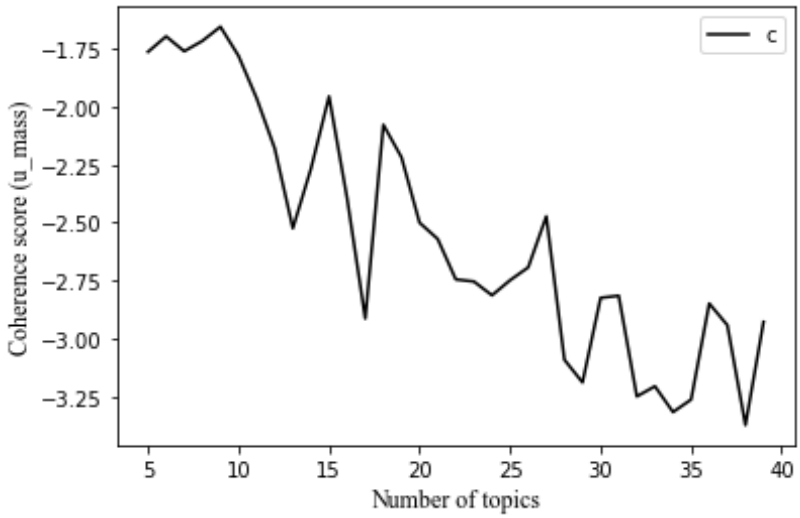
2.4. Data Analysis

After the preprocessing stage, LDA based topic modeling analysis was performed with the data set ready for analysis. LDA calculates the topic distribution per document, the word distribution per topic, and the topic and word assignments per document using an iterative process based on the Dirichlet distribution (Blei, 2012). In this study, the Gensim library, a comprehensive toolkit developed for text mining and topic modeling in Python, was used to adapt and apply the LDA based topic modeling procedure to the PBL corpus (Prabhakaran, 2018). In order to adapt the LDA model to the corpus, the initial values of the parameters of α, which determines the topic distribution in the documents, and β, which determines the distribution of the words in the topics, were chosen as default.

In the pilot analysis, it was observed that the words “problem”, “based”, “learning” and “pbl” were used in almost every topic. Since the corpus is directly in this field, two field experts were consulted and it was decided to add these two words to the stop words. Then, LDA analysis was performed again.

“u_mass coherence measure” was taken into account in determining the appropriate number of topics in the LDA analysis. U_mass value is accepted as one of the best coherence measure methods used to determine the ideal number of topics (Mimno, Wallach, Talley, Leenders & McCallum, 2011). As the number of topics increases, the umass value decreases. However, intuitive inferences can be made on the break-peak points of the umass graph (Gurcan & Cagiltay, 2022; Mimno et al., 2011). In this context, to empirically select the ideal number of topics (K), the LDA model was applied iteratively with different K values ranging from 5 to 40, and a u_mass coherence measure (c) was calculated for each K. Figure 2 shows the graph of the u_mass c value obtained for each K value between 5-40 using the u_mass semantic consistency approach. The clarity and semantic consistency of the discovered topics at these points were evaluated by the researchers by taking into consideration the important break-peaks (models with 6, 9, 15, 18, 27, and 31 topics in figure 2). It was decided that the model with 18 topics was appropriate, with a maximum consistency score (K = 18; u_mass_c=-2.077) reflecting the suitability and consistency of the topics distributions within these breakpoints.

Figure 2. Number of topics-u_mass coherence measure graph for 5-40 topics



The significance and consistency of these topics, which are explained with representative keywords, were evaluated by two experts working in the field of PBL, apart from the researchers. After examining the consistency of the topics, the label of each topic was determined and assigned by two field experts and researchers, taking into account the descriptive keywords of the topics. After naming the topics, the percentage of each topic per document, the distribution of words in each topic and the distribution of the topics in the entire corpus were calculated. At the end of this process, 15 representative key terms with the highest frequency were selected for each of the 18 topics. As a result, trend analyzes were performed with these 18 topics discovered by LDA, taking into account the u_mass consistency metric and semantic analysis.

3. RESULTS

In this research, which aims to examine the studies on the PBL approach in terms of content and descriptiveness, answers to five research questions were sought. The findings of the research are presented within the framework of the research questions.

3.1. Distribution of PBL Studies by Years (RQ1)

In the first research question of the study, the distribution of PBL studies by years was examined. The distribution of 7289 articles included in the research by years is given in Figure 3.

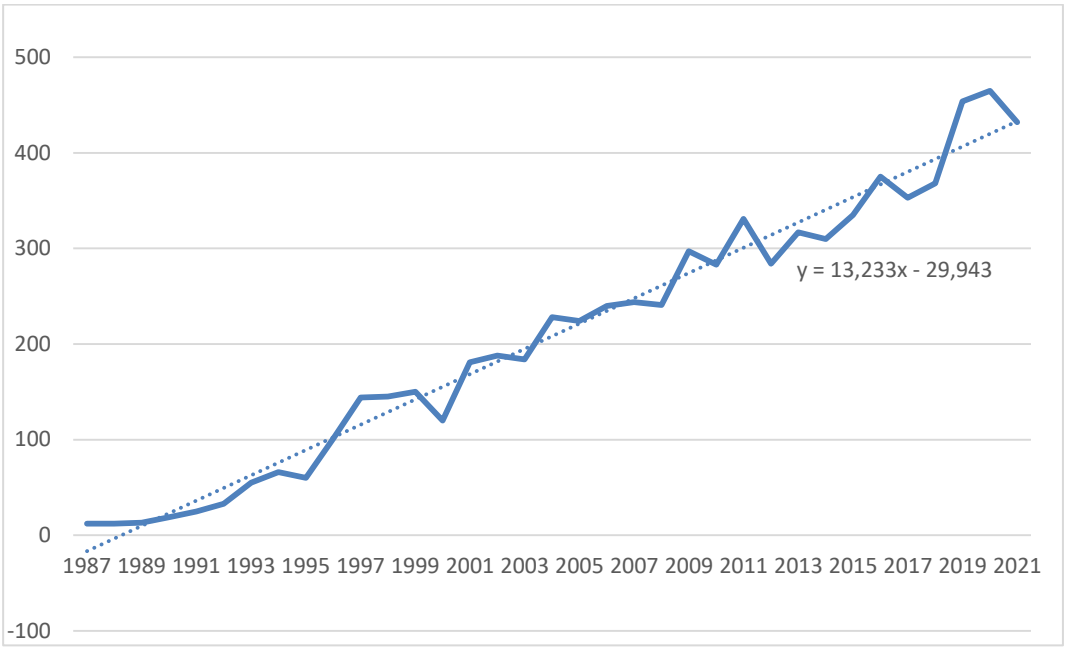


Figure 3. Distribution and slope of PBL studies by years

When Figure 3 is examined, the number of publications for 35 years in the field of PBL and the change in the number of publications by years are seen. As seen in Figure 3, PBL studies have increased linearly over the years. It can be said that it has reached the highest number of publications in recent years.

3.2. Subject Areas in PBL Studies (RQ2)

In the second research question of the study, the subject areas where PBL studies were conducted were examined. It has been observed that PBL studies are intensified especially in the subject of Social Sciences. Data on other subject areas in PBL studies are given in Figure 4.

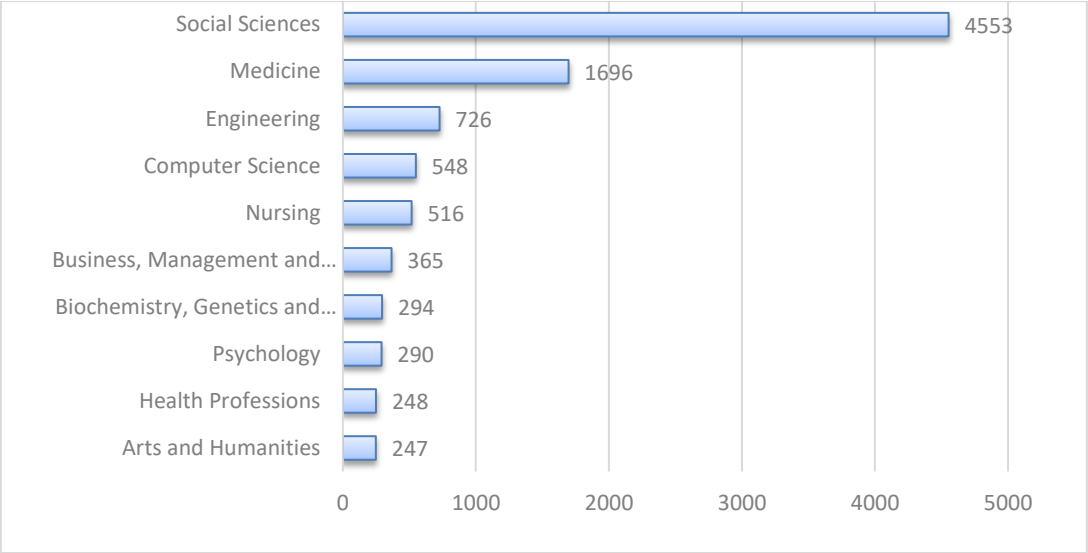


Figure 4. Subject areas in PBL studies

When Figure 4 is examined, it is seen that PBL studies stand out in the subject of Medicine (n=1696), Engineering (n=726) and Computer Science (n=548), especially in Social Sciences (n=4553). It is noteworthy that PBL studies were also carried out in studies conducted in different sub-fields of medicine such as Nursing, Psycology and Health Progessions.

3.3. Prominent Authors and Countries in PBL Studies (RQ3)

The third research question of the study is about examining the prominent authors and their countries in PBL studies. Schmidt, H.G. He is researcher who has the highest number of study in the field of PBL with 62 studies. Data on other researchers are given in Figure 5.

Figure 5. Prominent authors in PBL studies

According to Figure 5, Dolmans, D.H.J.M. with 46 studies, Van Der Vleuten, C.P.M. with 37 studies, are the authors who have conducted the highest number of the study in the field of PBL following Schmidt. When we look at the countries where studies in the field of PBL are carried out, United States was in the first rank with 1963 studies. The number of studies carried out in other countries is given in Figure 6.

Figure 6. Prominent countries in PBL studies

According to Figure 6, while the United States was in the first rank out and away with 1963 articles in the studies in the field of PBL, United Kingdom with 687 articles, Australia with 478 articles and Canada with 432 articles contributed to the studies in the field of PBL.

3.4. Prominent Topics in PBL Studies (RQ4)

The fourth research question of the study is about the prominent topics in PBL studies. These topics will provide the information to determine the research interests and trends in the field of PBL. LDA based topic modeling analysis was conducted to determine the topics studied in the field of PBL. As a result of the analysis, 18 prominent topics were determined. First 15 terms that make up each topic are listed and examined according to their intensities. In the naming stage of the topics, support was received from three field experts who worked in the field of PBL. The topics that emerged as a result of the LDA analysis, the terms that make up the topics and the volume ratios of the topics are presented in Table 1.

Table 1. Discovered topics, terms that make up the topics and volume ratios

Topics	Topic terms	Rate (%)
education curriculum	curriculum, education, teaching, practice, development, school, student, change, university, method, educational, professional, experience, nan, challenge	39.15%
teaching strategies	student, skill, solving, knowledge, teaching, strategy, ability, analysis, environment, learner, activity, task, teacher, case, writing	14.90%
critical thinking skill	student, thinking, test, skill, critical, effect, self, model, significant, solving, analysis, achievement, ability, school, method	12.29%
patient simulation	student, case, patient, simulation, clinical, pharmacy, medical, experience, scenario, facilitator, concept, knowledge, skill, interprofessional, care	8.88%
engineering education	engineering, student, project, skill, team, design, education, development, methodology, teaching, role, teamwork, model, analysis, work	6.11%
flipped classroom	student, teacher, science, teaching, classroom, method, methodology, education, model, flipped, active, development, strategy, skill, evaluation	3.51%
dental education	student, dental, perception, curriculum, method, undergraduate, questionnaire, experience, medical, self, education, perceived, response, survey, academic	3.35%
computer aided education	education, computer, database, teaching, analysis, technology, creativity, map, systematic, evidence, method, online, digital, educational, concept	2.48%
nursing education	nursing, student, education, health, nurse, care, patient, method, clinical, professional, intervention, attitude, practice, skill, program	2.44%
medical education	medical, student, clinical, curriculum, method, teaching, school, knowledge, medicine, lecture, examination, traditional, performance, education, basic	1.36%
virtual teaching	teaching, virtual, method, web, game, ethic, online, technology, evaluation, clinical, patient, training, practice, platform, ebm	1.08%
radiology education	teaching, radiology - cbl, education, method, china, analysis, , chinese, meta, student, medical, coaching, information, model, lbl	1.06%
therapy training	training, occupational, therapy, social, work, leadership, education, program, video, trainee, professional, practice, psychiatry, development, programme	1.03%
peer assessment	tutor, student, assessment, faculty, tutorial, peer, teaching, feedback, evaluation, method, medical, resident, training, self, program	0.91%
project based learning	student, design, project, system, solving, development, skill, engineering, model, environment, technology, case, information, learner, collaborative	0.51%
health care education	health, care, community, program, information, library, public, education, training, medicine, literacy, curriculum, university, veterinary, medical	0.43%
online education	education, student, online, case, medical, educational, teacher, knowledge, teaching, university, technology, development, higher, environment, experience	0.30%
clinical education	practice, education, clinical, skill, care, program, continuing, educational, intervention, module, change, professional, participant, training, physician	0.22%

It is seen in Table 1 that the most studied topic in the studies in the field of PBL is “education curriculum” with 39.15%. Together with the “education curriculum” (39.15%), “teaching strategies” (14.90%), “critical thinking skill” (12.29%) and “patient simulation” (8.88%) topics constitute almost 3/4 of the studies in the field of PBL. It has been revealed that the topics of “online education” (0.30%) and "clinical education" (0.22%) are among the least studied topics in PBL studies. Considering the general distribution of the topics, it is possible to say that the topics in the field of

medicine are in the majority among 18 topics. In fact, it has been determined that more specific areas of medicine such as “dental education” (3.35%), “radiology education” (1.08%) and “therapy training” (1.03%) are frequently included in PBL studies.

3.5. Temporarily changes of prominent topics in PBL studies (RQ5)

The fifth research question of the research is about how the prominent topics in PBL studies change temporarily. As well as the prominent topics in PBL studies, the change of these topics over time is also very important for the field of PBL. In this context, PBL studies conducted in 1987-2021 were analyzed in seven five-year periods. The findings obtained as a result of the analysis are given in Table 2.

Table 2. Distribution of the number of articles on the topics by five-year periods

Topics	Periods							**Total**
	1987-1991	1992-1996	1997-2001	2002-2006	2007-2011	2012-2016	2017-2021	
	1	2	3	4	5	6	7	
Education curriculum	53	172	396	473	537	569	654	**2854**
Teaching strategies	4	29	71	115	216	281	370	**1086**
Critical thinking skill	5	15	37	98	156	218	368	**897**
Patient simulation	3	21	60	113	129	138	183	**647**
Engineering education	0	11	12	47	86	117	172	**445**
Flipped classroom	1	9	13	25	48	71	89	**256**
Dental education	6	18	35	45	45	50	45	**244**
Computer aided education	1	7	25	19	29	43	57	**181**
Nursing education	2	7	24	30	40	39	36	**178**
Medical education	3	8	20	19	27	13	9	**99**
Virtual teaching	0	2	3	15	17	20	22	**79**
Radiology education	1	4	6	15	18	14	19	**77**
Therapy training	2	5	14	18	16	11	9	**75**
Peer assessment	0	2	12	15	10	17	10	**66**
Project based learning	0	0	3	10	7	9	8	**37**
Health care education	1	4	4	3	9	2	8	**31**
Online education	0	1	3	3	3	7	5	**22**
Clinical education	0	0	2	1	3	2	8	**16**
Total	**82**	**315**	**740**	**1064**	**1396**	**1621**	**2072**	**7289**

According to Table 2, it can be said that the topic of "education curriculum" continues to increase its volume in PBL studies in every period. Especially in the period of 1997-2001, studies on the “education curriculum” increased by approximately 230% compared to the previous period. Similarly, there were significant increases in “teaching strategies” and “patient simulation” in the same period. By looking at the increase in the number of studies on the topics in the periods, the topics with the highest increase rate in each period compared to the number of publications in the previous period were determined and are presented in Figure 7.

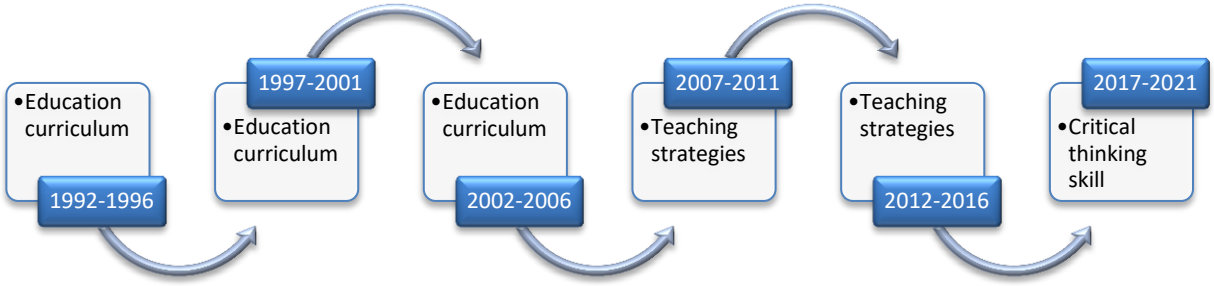


Figure 7. Topics with the highest increase in the number of researches by period

According to Figure 7, the topic of “education curriculum” between the years 1992-2006 has been the topic that increased the number of studies the most compared to the previous five-year period. Between 2007 and 2016, the topic of "teaching strategies" was the first topic to increase the number of researches compared to the previous period. In the last period, the topic of "critical thinking skill" became prominent among other topics. In order to examine the temporal changes of the prominent topics in the PBL studies more clearly, the volumes and slopes of the topics in the periods were calculated and their graphs were created. Periods are shown on the horizontal axes of the graphs, and the number of publications in that period is shown on the vertical axes. The resulting graphics are presented in Figure 8.

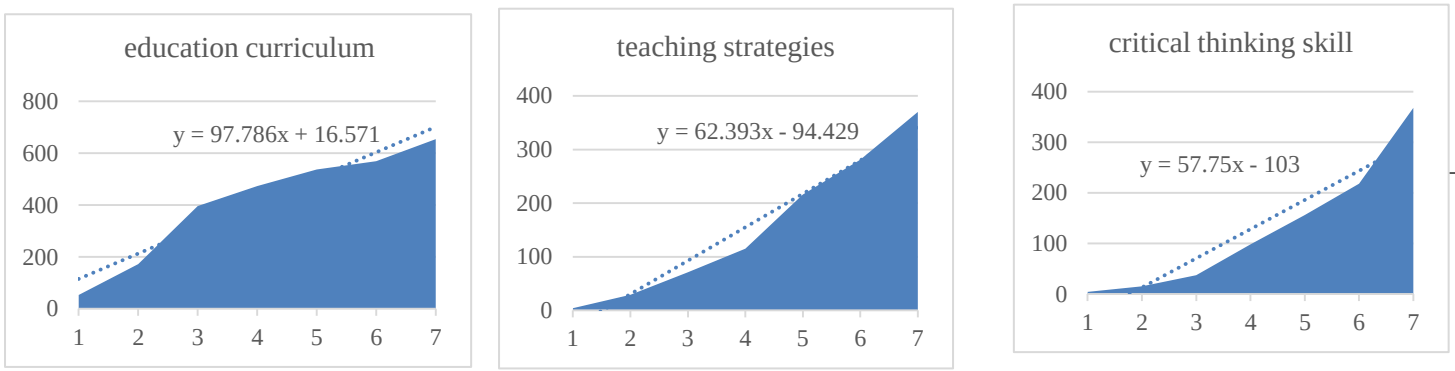


Figure 8. Volumes and slope graphs of all topics within periods

Figure 8 shows the graphs of the top three subjects according to their volume densities. When the graphics are examined, the "education curriculum" is the most voluminous topic among the topics studied in the field of PBL. In addition, “education curriculum” has become prominent as the topic with the fastest growing volume among other topics (Acc=97.78). In other words, “education curriculum” in PBL studies has been the topic that has the highest rate of increase in terms of the number of publications in five-year periods. The topics of “teaching strategies” and “critical thinking skill” also came first in terms of volume and acceleration among other topics. The volume graphs of the topics compared to other topics and their trends are presented in Figure 9. In the created graphs, the horizontal axis shows the periods, the vertical axis shows the percentages of the topic in that period. The order of the topics is organized according to the magnitude of their acceleration and the graph of the first three ranked topics is included.

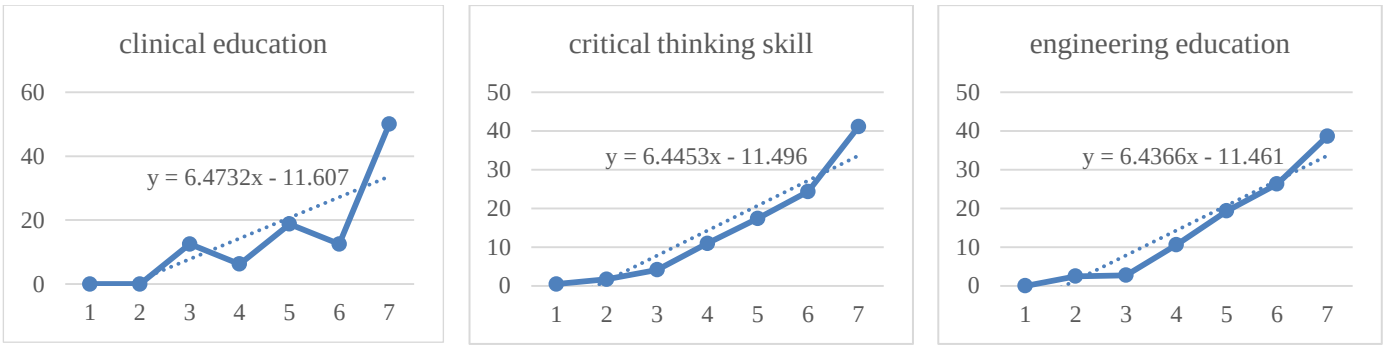


Figure 9. Percentage and acceleration graphs of each topics compared to other topics within periods

As a result of the analysis, it was seen that the topic of "clinical education" was the most accelerated topic (Acc=6.47). In addition, it was determined that the topics of "critical thinking skill, engineering education, flipped classroom, teaching strategies, virtual teaching, computer aided education, and patient simulation" were above the average acceleration. Considering the number of publications of the relevant topics in each period, the percentage rate compared to other topics was calculated. Again, a slope value (AccPTP = Percent acceleration relative to other topics in periods) was determined upon these percentages. The slope values of the topics were calculated based on the data obtained according to the results of the LDA analysis. According to the results of the analysis, while the percentage weights of 11 topics increased over time compared to other topics, the percentage weights of 7 topics decreased. The percentage distribution of all topics within the topics studied over time is given in Figure 10.

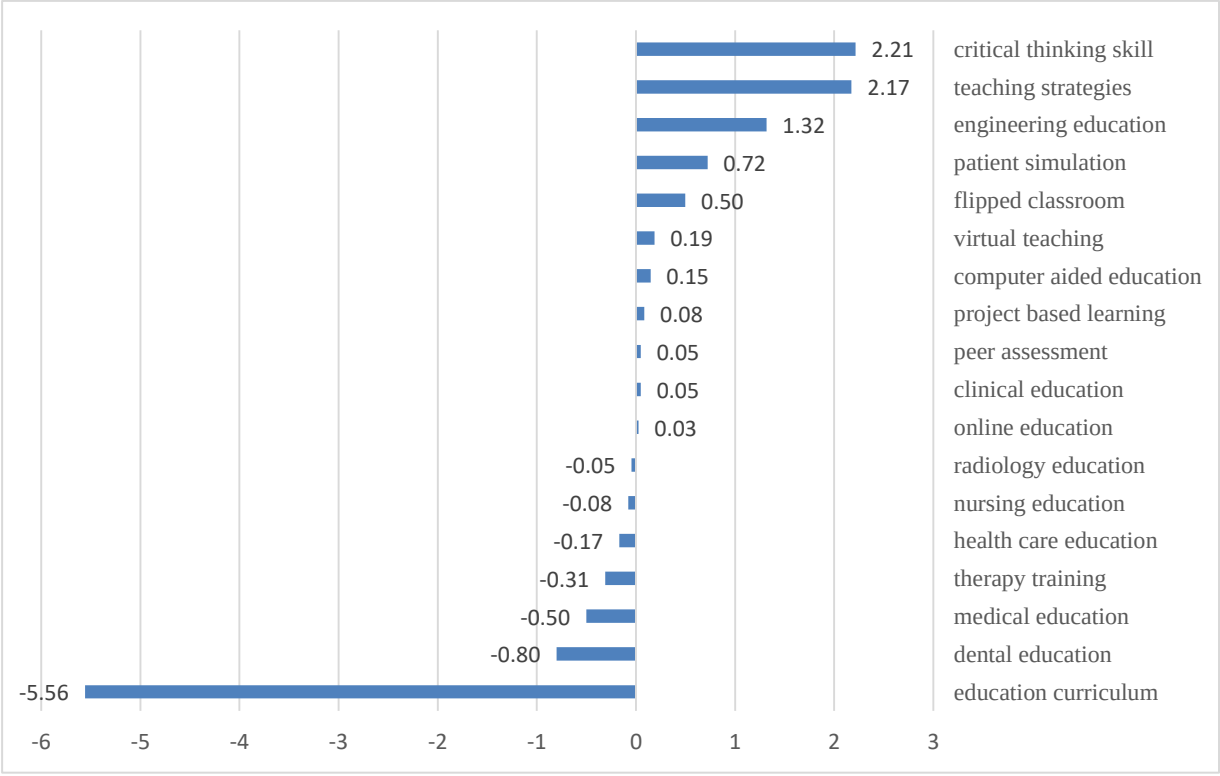


Figure 10. Acceleration values of all topics compared to other topics

According to Figure 10, it is seen that the topics of "critical thinking skill" (AccPTP = 2.21) and "teaching strategies" (AccPTP = 2.17) accelerate more than the other topics. On the other hand, the topic of "education curriculum" (AccPTP = -5.56) became the topic whose percentage weight decreased the most compared to other topics.

4. DISCUSSION AND CONCLUSIONS

In this study, it is aimed to examine the studies based on the PBL approach in terms of descriptive analysis and topic modeling based semantic content analysis. Before moving on to the results of the research, it is important to draw attention to the limitations of the research and to evaluate the results within the framework of these limitations. In this context, the LDA algorithm, which was first used for topic modeling analysis, can be expressed as one of the limitations of the study. The second limitation can be said that only the articles were selected from the study types in the selection of the studies to be analyzed. Finally, the keywords used in the database scans in the selection of the studies can be considered as a limitation of the research.

First of all, descriptive features of the studies in the field of PBL were examined within the framework of the purpose of the research and research questions. In this context, the distribution of PBL studies by years, subject areas, countries and researchers who have conducted the most research have been examined. In the examination, it was determined that the number of PBL studies continued to increase over the years. When the literature is examined, it is seen that PBL is widely used in many education levels from secondary education (Wilder, 2015) to nursing education (Ghani, Rahim, Yusoff & Hadie, 2021).

In terms of the research fields in PBL studies, “Social Sciences”, “Medicine” and “Engineering” took the top three ranks. According to the results of the study, it is possible to say that the PBL approach is used in different disciplines. Similarly, Savery (2006), Majeski and Stover (2005) define the PBL approach as an approach that can be used in different disciplines and interdisciplinary learning activities. However, Stentoft (2017) states that a comprehensive approach on how to organize PBL to support interdisciplinary learning has not yet been developed. It is thought that future studies in this context will make significant contributions to the literature. On the other hand, the prominence of different fields of study, especially in the field of medicine, such as “Nursing”, “Psycology” and “Health Progessions” is remarkable. Considering that the first applications of PBL in learning environments were made in the field of medicine (Schmidt, 1983) and the applications in other disciplines were realized after successful applications in the field of medicine, it is not surprising that the use of PBL is widespread in the sub-disciplines of medicine. In PBL studies, United States ranked first with 1963 research, while United Kingdom (n=687) ranked second and Australia (n=478) ranked third. In terms of the researchers with the highest number of study in the field of PBL, Schmidt, H.G. (n=62) and Dolmans, D.H.J.M. (n=46) become prominent. In the studies conducted by Hallinger (2021) and Zhang, Wang, Bai and Zhang (2022), the country with the highest number of studies in the field of PBL is the United States, while Schmidt, H.G. and Dolmans, D.H.J.M. in the top ranks in terms of the authors with the highest number of publications.

After examining the descriptive features of PBL studies, the topics studied in the field of PBL and their temporal changes were examined. As a result of the LDA analysis, it was determined that the studies in the field of PBL concentrated on 18 topics. Among these topics, "education curriculum" (39.15%), “teaching strategies” (14.90%) and “critical thinking skill” (12.29%) are in the top three ranks. At the same time, these three topics make up more than half of the total study field (66.34%). The fact that these topics constitute a large part of the studies in the field of PBL can be explained by the change in expectations from the learning process and education systems. In recent years, it has been observed that in many teaching levels, especially in medical education, the development of skills such as critical thinking and problem solving has been the focus point (Merisier, Larue & Boyer, 2018). Similarly, according to Al-Azri and Ratnapalan (2014) many universities and educational institutions try to use PBL as a teaching model and continue their research and development activities in this direction. Two factors can be effective in bringing these three issues to the fore: First, expectations in education systems shapes around skills such as critical thinking skills, taking

responsibility for one's own learning and problem solving, which are accepted as 21st century skills. Second, educational institutions make efforts to evaluate PBL as a holistic learning model. In addition to these, it has been determined that topics such as “peer assessment”, “project based learning”, “health care education”, “online education” and “clinical education” are studied proportionally below 1%.

The results of the LDA analysis showed that the “education curriculum” continued in PBL studies by increasing the number of publications over the years. “education curriculum” stood out as the topic that increased its volume the fastest among other topics (Acc=97.78). In other words, “education curriculum” in PBL studies has been the topic that increased the number of publications the most in five-year periods. Looking at the years 1987-2021 within five-year periods, it has been determined that the "education curriculum" has increased the most in the period of 1997-2001. Hallinger (2021), in his study, examined the PBL field in five-year periods, and as a result of his analysis, it was determined that the studies and citation rates in the field of PBL increased rapidly, especially in the period 1995 and later. From this point of view, the highest increase in the "education curriculum" in 1997-2001 may be due to the increase in all topics in the field of PBL during these periods.

As a result of the analysis, it was seen that the topic of “clinical education” was the most accelerated topic (Acc=6.47). In addition, it was determined that the topics of “critical thinking skill, engineering education, flipped classroom, teaching strategies, virtual teaching, computer aided education, and patient simulation” were above the average acceleration. It was revealed that the three least accelerated topics were “medical education” (Acc=1.26), “therapy training” (Acc=1.66) and “health care education” (Acc=2.53). Clinical education is a very important link that brings together university education and professional business life, providing students with the opportunity to apply the knowledge they have acquired during their university education in the field of medicine and nursing in their natural environment (Williams, 1999). PBL is very suitable for clinical education because of the opportunities it provides for students to apply their theoretical knowledge by exposing them to real-life problems in the learning process (Tiwari et al., 2005). In this context, it is expectable situation that the use of PBL in clinical education will become more widespread than in other topics. Although the needs of clinical education and the opportunities offered by PBL largely overlap, there are still significant challenges in applying PBL to different disciplines (Brown, 2022). In addition, some problems such as crowded classrooms in fields considered suitable for PBL use, such as clinical education (Cash, Letargo, Graether & Jacobs, 2017), create significant problems in the use of PBL. In this context, in future research, identifying the problems encountered especially in the topics where PBL is widely used, and proposing solutions for these problems are important.

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