

INTRODUCTION

With increasing social complexity and uncertainty, humans face more complex problems in open social systems, such as environmental pollution brought about by using fossil fuels and safety threats posed by genetically modified foods. Thus, problem-solving skills are becoming essential to solving complex problems in the daily environment. The concept of problem-solving skills was first detailed and systematically studied by Charles E. Merrill in the 1950s; Merrill developed a problem-based learning model that promoted problem-solving as the primary method of acquiring knowledge and skills (Hung et al., 2008). Problem-solving skills are abilities based on identifying problems, finding alternative solutions, and applying the best solution in a relatively new situation (Araiza-Alba et al., 2021; Graesser et al., 2018; Pinter & Cisar, 2018). Problem-solving skills involve cognitive processes such as constructing, representing, analyzing data, identifying, planning, and searching for solutions, which is an approach to achieving meaningful learning (Lu & Xie, 2024; Zhou et al., 2019). By mastering these skills, humans can overcome real-life problems by applying the knowledge they already have and as self-preparation in human development to face complex problems (Yalçın, 2022).

Researchers have explored the origin of the concept of problem-solving skills and discussed its definition classification based on their subject knowledge, which makes these skills have transdisciplinary characteristics (O'neill et al., 2019). The academic literature has raised several critical theoretical, conceptual, and empirical issues, but there has yet to be a consensus. As fragmented yet interconnected societal challenges coexist, this skill is of paramount importance and requires cooperation between different disciplines. (Hou et al., 2022). However, problem-solving skills still need to be empowered and enhanced in learning. (Machmud et al., 2023; Makwakwa et al., 2024). Learning that emphasizes problem-solving allows an individual to build conceptual and procedural knowledge. (Liu & Israel, 2022).

Problem-solving skills can be trained transdisciplinarily through science, technology,

engineering, mathematics (STEM), and design thinking learning. STEM-design thinking learning design can significantly improve problem-solving skills (Chin et al., 2019; Guaman-Quintanilla et al., 2022; Léger et al., 2020; Phang et al., 2019; Thi-Huyen et al., 2021; Yalçın & Erden, 2021; Zhou et al., 2019) Through the stages of STEM-design thinking learning, students are used to constructively build knowledge in the environment in groups by exploring the problem space. (Guaman-Quintanilla et al., 2022). In addition, STEM learning, incorporating the design thinking process, is the most agreed context for enhancing effective science learning in problem-based learning. (Aydin-Gunbatar et al., 2018). In PBL, students face real, authentic problems in a social context for students and follow the material. Thus, student activities are no longer listening, recording, and memorizing material but instead directed to critical thinking, problem-solving, communication, collaboration, and creativity (Ratminingsih et al., 2021). STEM Design Thinking can be applied using PBL syntax in its learning.

Problem-based learning (PBL), design thinking (DT), and science, technology, engineering, and mathematics (STEM) on problem-solving (PS) skills are a growing research trend that supports 21st-century skills. Problem-based learning is a learning model that provides real-world problems to students to facilitate learning about critical thinking and problem-solving skills to acquire essential knowledge and concepts (Darhim et al., 2020). PBL is a student-centered learning model that guides students in group learning through activities such as problem analysis, goal setting, resource gathering, idea synthesis, and problem-solving experiences (Chueh & Kao, 2024); DT is learning that can enhance student creativity and foster design interest (He et al., 2023). STEM is learning that emphasizes experiential and interdisciplinary approaches to real-life problems based on knowledge (Şahin et al., 2024).

Bibliometric analysis needs to be done to see how far the research trend towards problem-solving needs to be done. Bibliometric analysis is an analysis that refers to the qualitative and quantitative evaluation of a particular research field using mathematics and statistical methods to understand the structure

of knowledge and explore development trends (Bornmann & Leydesdorff, 2014). Bibliometric article reviews will be reviewed using seven keywords that have been determined. Previous research results obtained: 1) There has been research on PBL and Problem-solving as conducted by Abesadze & Nozadze, (2020), Lonergan et al., (2022), and Prahani et al., (2022) (Abesadze & Nozadze, 2020; Lonergan et al., 2022; Prahani et al., 2022) but still limited to examining the secondary school level, reinforced bibliometrics by Chomiak-Orsa et al., (2023) about creative problem-solving learning (Chomiak-Orsa et al., 2023). 2) Research related to Design Thinking and Problem-solving has been conducted by Bertão et al. (2023) and VanGronigen et al. (2023), reinforced by bibliometrics related to problem-solving but has not included design thinking (Bertão et al., 2023; VanGronigen et al., 2023). 3) STEM and problem-solving have been researched by Braun et al. (2022), Sari et al., (2022), and Scholkmann et al., (2023) but have not been reinforced with bibliometrics (Braun et al., 2022; Sari et al., 2018; Scholkmann et al., 2023). 4) Research related to PBL and DT and problem-solving has been investigated by Tawfik et al. (2021) but has not been strengthened with bibliometrics. 5) PBL STEM and Problem-solving have been researched by Leijon et al. (2020) and Nguyen (2023) (Leijon et al., 2020; Nguyen, 2023) But have not been strengthened with bibliometrics. 6) Research related to DT STEM and problem-solving has been conducted by Ananda (Ananda, 2019) But has not been strengthened by existing bibliometrics. 7) Research related to PBL, DT, STEM, and problem-solving has never been done, and no bibliometrics exist.

This research differs from previous research, namely the focus on PBL DT STEM and PS, which will be carried out in higher education and students; after being analyzed bibliometrically, it will be deepened in content analysis. Content analysis is obtained from keyword reduction, abstracts, and research results that use PBL, DT, STEM, and PS keywords. Bibliometric research and content analysis are sourced from the Scopus database from 2018-2023. The focus of this research is also different from previous research, which is fully stated in the following research questions:

- 1) What is the distribution of publications on PBL, DT, STEM, and their integration on problem-solving among countries in the world?
- 2) What are the research trends related to PBL, DT, and STEM topics on Problem-solving?
- 3) What are the most widely used research methods and instruments in PBL, DT, and STEM research on Problem Solving in higher education?
- 4) What are the research results related to PBL, DT, and STEM on Problem-solving?

METHOD

The method used in the research is quantitative, using bibliometric and content analysis techniques. Bibliometric mapping investigates articles about Problem-Based Learning, Design Thinking, and STEM on problem-solving skills. The bibliometric method is divided into four main stages: research mapping stage, Problem-Based Learning, Design Thinking, STEM publication map stage, thematic analysis stage, and conclusion. The first step is data mapping. The author's primary data source is the Scopus database. Scopus

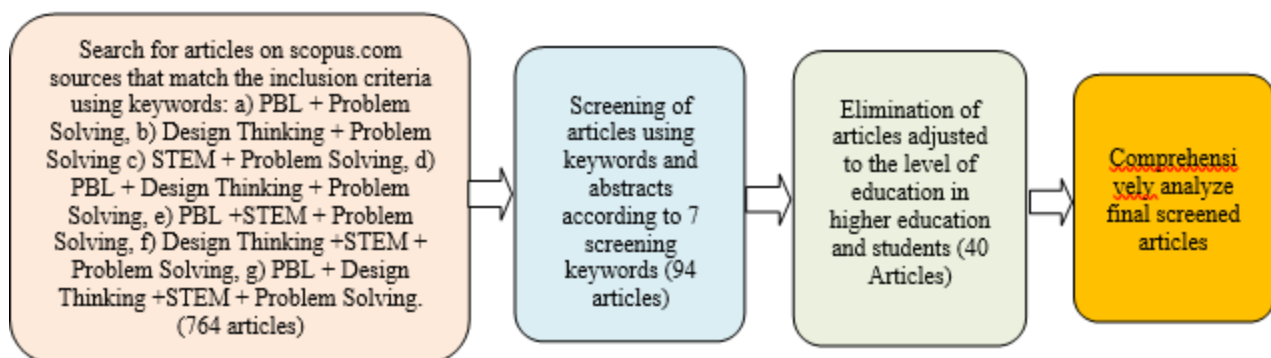


Fig. 1: Stages of the research method

was chosen because it is one of the most extensive and comprehensive published document indexes, contains metadata from reputable journals, and supports bibliometric analysis. The document search was conducted on August 30, 2023, with the keywords “a) PBL+Problem Solving, b) Design Thinking+Problem Solving c) STEM+Problem Solving, d) PBL+Design Thinking+Problem Solving, e) PBL+STEM+Problem Solving, f) Design Thinking+STEM+Problem Solving, g) PBL+Design Thinking+STEM+Problem Solving.” The bibliometric analysis in this article used inclusion and exclusion criteria to select appropriate documents. The inclusion criteria are as follows:

- 1) Year of publication: 2018-2023
- 2) Field area: Social Science
- 3) Document type: article
- 4) Publication stage: final
- 5) Language: English.
- 6) Source type: journal

RESULTS AND DISCUSSION MM

The study’s results obtained 764 articles from the scopus.com data source that met the data inclusion criteria. The data will be analyzed to see research trends for the last six years (2018-2023) using bibliometric analysis using VOS Viewer and Microsoft Excel. The results obtained include publication distribution, research topic trends, and authors who do much research related to PBL, DT, and STEM on Problem Solving.

The bibliometric analysis was followed by content analysis by filtering articles based on keywords and

abstracts corresponding to the seven topics described in Table 1. The elimination of the first article resulted in 94 articles matching each topic keyword. The next analysis stage was based on articles that used student subjects or higher education. This was intended to see learning patterns in higher education that used learning strategies using PBL, DT, and STEM to solve problems in students. The results of the second elimination were 40 articles, which will be analyzed regarding the methods, instruments, and research results obtained.

The following is a more complex explanation in paragraphs: Problem formulations 3.1 and 3.2 describe bibliometric analysis in detail, and problem formulations 3.3 and 3.4 describe detailed content analysis.

The distribution of publications on PBL, DT, STEM, and their integration into Problem Solving among countries

This analysis of PBL, STEM, and DT publications by country aims to determine which countries have published the most influential articles on these topics. Figure 2 illustrates the top ten countries with publications on PBL, STEM, and DT topics and the integration of these three out of 79 countries.

Figure 2 shows that the United States has the most publications, with 160 articles (20.94%). This result is based on the bibliometric analysis conducted by previous studies, in which the United States has always been the largest contributor to publications on STEM education. (Gil-Doménech et al., 2020; Zhan

Table 1: Distribution of articles in bibliometric analysis and content analysis

No	Topic	Total Scopus Articles	Articles analyzed based on keywords and abstracts	Articles analyzed at the tertiary level
1	PBL and Problem Solving	376	41	17
2	Design Thinking and Problem Solving	213	8	6
3	STEM and Problem Solving	143	32	12
4	PBL, DT, and Problem Solving	7	2	1
5	PBL, STEM, and Problem Solving	7	8	4
6	DT, STEM, and Problem Solving	19	3	0
7	PBL, DT, STEM, and Problem Solving	0	0	0
Total		764	94	40

No	Authors	Year	Country	Educational stage	Study Design	Instrument
11	Henriksen. D., Gretter. S., & Richardson. C	2020	USA	Student of University	Qualitative	Interview
12	Liso. V	2020	Denmark	Student of University	Qualitative	Interview
13	Zimmerman R., Maker C., Alfaiz F	2020	Saudi Arabia	Student of University	Qualitative	Test, Observation
14	Alfaiz F., Pease R., Maker C	2020	Saudi Arabia	Student of University	Quantitative	Questionnaire
15	Priemer. B., et al	2020	Germany	Teacher	Mix method	Framework
16	Stehle S., Peters-Burton E.	2020	USA	Teacher	Mix method	Assessment Rubric
17	Dmitrenko N., Dolia I., & Nikolaeva S	2020	Ukraine	Student of University	Quantitative	Test
18	Rehmat A.P., & Hartley K	2020	Las Vegas	Student of University	Quantitative	Test
19	Tawfik. A., et al	2021	North Georgia	Teacher	Qualitative	Interview
20	Bistulfi G.	2021	USA	Student of University	Mix method	Test, Questionnaire
21	Lin. C., Tu. H	2021	Taiwan	Student of University	Qualitative	Interview, observation
22	Salgado-Chavarría & Palacios-Alquisira	2021	Mexico	Student of University	Qualitative	Observation, literature review
23	Wang C	2021	Taiwan	Pre service teacher	Mix method	Interview, Observation, test
24	Vidad D., & Quimbo M	2021	Philippines	Student of University	Quantitative	Test
25	Crichton. M., Crichton. H., & Colville. G	2022	England	Student of University	Qualitative	Open Questionnaire and Close Questionnaire
26	Rofik. A., et al	2022	Indonesia	Pre service teacher	Quantitative	Test
27	Braun. I., Langner.A., & Graulich. N	2022	Germany	Student of University	Qualitative	Observation, Interview
28	Sari. U., et al	2022	Turkey	Pre service teacher	Quantitative	Test
29	Su. K	2022	Taiwan	Student of University	Quantitative	Test
30	Yilmaz. G	2022	Turkey	Student of University	Qualitative	Case Study
31	Wynn. C	2022	USA	Student of University	Qualitative	Interview
32	Amanda F., et al	2022	Indonesia	Student of University	Quantitative	Test

No	Authors	Year	Country	Educational stage	Study Design	Instrument
33	Huang. X	2022	Malaysia	Pre service teacher	Quantitative	Test
34	Scholkmann. A., Stegeager.N., & Miller R.K	2023	Denmark	Student of University	Qualitative	Questionnaire
35	Nguyen T	2023	Vietnam	Teacher	Quantitative	Questionnaire
36	DeWaters.J., & Kotla. B	2023	USA	Student of University	Quantitative	Test, Questionnaire
37	Khwaengmek V., & Faikhamta C	2023	Thailand	Pre service teacher	Quantitative	Questionnaire
38	Bertão R.A., et al	2023	Korea	Employees	Qualitative	Documentation, literature review, observation
39	Toker S., & Akbay T	2023	Turkey	Pre service teacher	Quantitative	Survey
40	Guerra A., Nørgaard B., & Du X	2023	Denmark	Student of University	Qualitative	Observation

Based on the year of publication, they are grouped as follows: 2018: 2 articles, 2019: 5 articles, 2020: 11 articles, 2021: 6 articles, 2022: 7 articles, 2023: 9 articles. The number of articles still being researched from year to year indicates that research related to problem-solving in PBL, DT, and STEM is still being carried out, and the interest related to research on these topics is large. The highest research interest was in 2020, with 11 publications; research from 2020 to 2023 continued to increase the number of publications. Based on the research countries, they are grouped as follows: UK: 2 articles, Denmark: 3 articles, Vietnam: 1 article, Indonesia: 7 articles, West Georgia: 1 article, Sweden: 1 article, America: 6 articles, Germany: 2 articles, Turkey: 4 articles, Thailand: 1 article, Taiwan: 3 articles, Saudi Arabia: 2 articles, Korea: 1 article, Australia: 1 article, Mexico: 1 article, Ukraine: 1 article, Las Vegas: 1 article, Malaysia: 1 article, Philippines: 1 article. These results indicate that research related to PBL, DT, and STEM is still developing well globally and is still a trend widely conducted in Indonesia. Indonesia contributed the most articles conducting research in higher education from general students and student teachers. This indicates that PBL, DT, STEM learning, and their integration are widely used in education.

Based on the research methods used, 20 articles (50%) used quantitative methods, 16 articles (40%) used qualitative methods, and four articles (10%) used mixed methods. The data shows that research in higher education focuses on the effect of applying PBL, DT, and STEM learning models on problem-solving skills. In addition, it looks at students' perceptions of the model/method/approach used to empower students in problem-solving. Based on the instruments or measuring instruments, there are various measuring instruments to find out how to improve problem-solving, including tests, observations, interviews, questionnaires, and documentation. The most widely used instrument is using tests. The test is an instrument measured by adjusting aspects and indicators to the research variables to provide more valid and reliable results.

Research results related to PBL, DT, and STEM on Problem-solving

The research results obtained variable results on as many as three topics, namely the integration of PBL+DT+STEM, which has been researched in empowering problem-solving, multidisciplinary PBL, DT, STEM, and research paradigm framework. The complete results are described in Table 3.

Table 3: Thematic analysis coding on the research result

Variable	Specific coding	References	Frequency
PBL+DT+STEM integration on PS	PBL and Problem Solving	(Amanda et al., 2022; Chamidy et al., 2020; Crichton et al., 2022; Darhim et al., 2020; Dmitrenko et al., 2020; Feehily, 2018; Guerra et al., 2023; Lin & Tu, 2021; Liso, 2020; Nahdi et al., 2020; Rofik et al., 2022; Salgado-Chavarría & Palacios-Alquisira, 2021; Sri Suryanti & Supeni, 2019; Susbiyanto et al., 2019; Toker & Akbay, 2022; Wang, 2021; Wynn, 2022)	17
	Design Thinking and Problem Solving	(Bertão et al., 2023; DeWaters & Kotla, 2023; Henriksen et al., 2017; Hong & Choi, 2019; Mosely et al., 2018; Yilmaz, 2022)	6
	STEM and Problem Solving	(Alan et al., 2019; Alfaiz et al., 2020; Bistulfi, 2021; Braun et al., 2022; Huang et al., 2022; Khwaengmek & Faikhamta, 2023; Peters-burton & Stehle, 2019; Priemer et al., 2020; Sari et al., 2018; Scholkmann et al., 2023; Stubbs et al., 2018; Vidad & Quimbo, 2021)	12
	PBL, DT, and Problem Solving	(Tawfik et al., 2021)	1
	PBL, STEM, and Problem Solving	(Leijon et al., 2020; Rehmat & Hartley, 2020; Su, 2022; Thi-Huyen et al., 2021)	4
Multidisciplinary of PBL,DT,STEM	Interdisciplinary dan multidisciplinary	(Alan et al., 2019; Alfaiz et al., 2020; Bistulfi, 2021; Braun et al., 2022; Chamidy et al., 2020; DeWaters & Kotla, 2023; Feehily, 2018; Glaze, 2018; Huang et al., 2022; Khwaengmek & Faikhamta, 2023; Leijon et al., 2020; Mosely et al., 2018; Peters-burton & Stehle, 2019; Priemer et al., 2020; Rehmat & Hartley, 2020; Sari et al., 2018; Scholkmann et al., 2023; Soysal, 2022; Su, 2022; Thi-Huyen et al., 2021; Vidad & Quimbo, 2021; Zimmerman et al., 2020)	21
Framework research of PBL+DT+STEM+PS	Application of integrated PBL+DT+STEM learning model to improve problem-solving skills	(Alan et al., 2019; Bertão et al., 2023; Chamidy et al., 2020; Henriksen et al., 2017; Priemer et al., 2020; Su, 2022; Tawfik et al., 2021; Yilmaz, 2022)	8

a. PBL+DT+STEM integration on PS

Problem Problem-based learning is a learning model that provides real-world problems to students by constructing their knowledge to facilitate learning about critical thinking skills and problem-solving to acquire important knowledge and concepts (Darhim et al., 2020; Liso, 2020; Nahdi et al., 2020). PBL is constructive learning that is divided based on constructive knowledge (cognitive) and socially constructive (Darhim et al., 2020; Sri Suryanti & Supeni, 2019; Susbiyanto et al., 2019). Design Thinking (DT) is a design program that allows looking at solutions from the point of view centered on the needs of people

from various cultural, economic, historical, and political backgrounds. (Hong & Choi, 2019; Mosely et al., 2018) DT is constructivist learning, where learning is based on experience that can develop students' cognitive ability to solve a design. Student involvement in learning includes activeness, asking questions, projecting, planning, and redesigning solutions in Design Thinking steps, which can improve students' problem-solving skills. (Chin et al., 2019; Guaman-Quintanilla et al., 2022; Léger et al., 2020; Thi-Huyen et al., 2021; Yalçın & Erden, 2021). Students' involvement in the creative process greatly influences achieving learning objectives at the Design Thinking

step. (Guaman-Quintanilla et al., 2022) Design Thinking helps students explore problems without creating hypotheses and theories. It allows students to gain an intuitive understanding by observing the situation and synthesizing information into different points of view (Balakrishnan, 2022; Chin et al., 2019; Guaman-Quintanilla et al., 2022). The problems faced by students are usually related to issues faced by society, such as water quality (Léger et al., 2020), environmental problems (Balakrishnan, 2022; Rao et al., 2022; Thi-Huyen et al., 2021; Yalçın & Erden, 2021), ecosystems, and energy (Chin et al., 2019), product packaging (Yang & Hsu, 2020), construction, agriculture, and natural disasters (Clark et al., 2020). This is certainly very related to Design Thinking learning because the purpose of the Design Thinking learning model is to find solutions to problems facing society (Balakrishnan, 2022; Calavia et al., 2021; Guaman-Quintanilla et al., 2022; Kijima & Sun, 2020; Thi-Huyen et al., 2021; Yang & Hsu, 2020).

STEM is a learning approach to integrate the specialized knowledge and skills of one discipline with at least other STEM disciplines; many better products emerge as a result of bringing together different disciplines (Alan et al., 2019). STEM is essential learning for dealing with the complexities and challenges of the world and for solving real-world problems (Zimmerman et al., 2020). STEM is a discipline that relies on external representations to understand scientific concepts and phenomena (Braun et al., 2022). STEM focuses on physical Computing, which can contribute to the development of students' entrepreneurial thinking and produce the necessary tools for national development and industrialization in their future careers (Sari et al., 2018). STEM uses constructivist and cognitivist in its learning (Braun et al., 2022).

Based on the research that has been studied, learning using PBL alone or purely produces three types of research results, namely, PBL significantly increases PS (Ahdhianto et al., 2020; Ahdhianto & Istiq'faroh, 2020; Argaw et al., 2017; Asogwa et al., 2021). PBL can improve PS, although it does not increase significantly (Chen et al., 2022). In addition, PBL cannot improve students' PS (Carriger, 2016). In this study, some previous researchers also combined PBL with other learning models, including

complexity science, flipped PARSER, AMES test, TPACK, collaborative learning, small groups, role-play, SMART, POE, character emphasis, contextual learning, local tribal tradition (handed), PjBL, and independent learning (Calavia et al., 2021; Glaze, 2018). The results showed that using PBL in combination improved students' PS. The combination of PBL with other learning models, technologies, and learning approaches has proven to be able to attract the interest, motivation, and ability of 21st-century students to solve given problems (Raman et al., 2024) PBL combined with DT STEM in the literature review can train problem-solving because it is disciplined and departs from the same theory. PBL is a learning model that is already good at improving problem-solving; integrated with DT STEM further strengthens practicing problem-solving.

b. Multidisciplinary PBL, DT, STEM on Problem Solving

21 of the 40 articles selected used integration of multiple disciplines. Not only integration in STEM+PS (12 articles), PBL+STEM+PS, or those that use STEM integration in learning. But also on the integration of PBL+PS and DT+PS, this indicates that not only in the STEM approach, which in theory and practice uses the four disciplines of Science, Technology, Engineering, and Mathematics but PBL and DT learning also raise the integration of various disciplines in empowering problem-solving. PBL uses cross-disciplines given to the problem to be solved using engineering, technology, and mathematics to produce a product from the expected problem.

In addition, specific to the learning of Natural Sciences is taught in an integrated manner with some modeling of science learning (Fogarty, 2009). Science is also an integration of the disciplines of physics, chemistry, and biology, so it is interdisciplinary. Multidisciplinary is inherent in the STEM approach, which integrates Science, Technology, Engineering, and Mathematics. STEM strongly embodies interdisciplinarity in science learning, where the integration of disciplines (multidisciplinary) produces better products that can realize real value by combining theoretical knowledge of physics, biology, chemistry, and mathematics with technological and engineering practices (Alan et al., 2019). Learning

skills in language arts, science, math, and technology and applying those skills and concepts in an integrated manner will exercise their creative problem-solving ability to propose innovative solutions to persistent problems (Zimmerman et al., 2020).

c. Framework research of PBL+DT+STEM+PS

Based on Figure 6. the relationship between PBL, DT, and STEM to problem-solving is described. In the research of Chamidy et al. (2020) (Chamidy et al., 2020) Problem-based learning is divided into five stages, namely 1) Identification of problems: Identifying problems based on real life. The first stage relates to the problem-solving aspect, namely recognizing that a problem exists. 2) Organizing the student: Students and the group will discuss related experimental designs for problem-solving. The second stage is related to the problem-solving aspect of establishing an understanding of the nature of the situation. 3) Monitoring and investigation:

students will be guided to collect data/information, look for explanations, and find solutions to solve problems. The third stage is related to the problem-solving aspect of planning a solution. 4) Development and presentation of problem-solving results: Students will make reports and results from discussions with the group as a solution to the problem. The fourth stage is related to the problem-solving aspect of carrying out the solution. 5). Problem-solving process analysis and evaluation: Students will be guided to analyze and re-evaluate the solutions they have made. The fifth stage is related to the problem-solving aspect of monitoring and evaluating progress throughout the activity.

Research by Henriksen, et al (2020), Bertão R.A., et al (2023), Yilmaz. G (2022) (Bertão et al., 2023; Henriksen et al., 2017; Yilmaz, 2022) the stages of design thinking are divided into five stages, namely: 1) Empathize: at the empathize stage, there will be

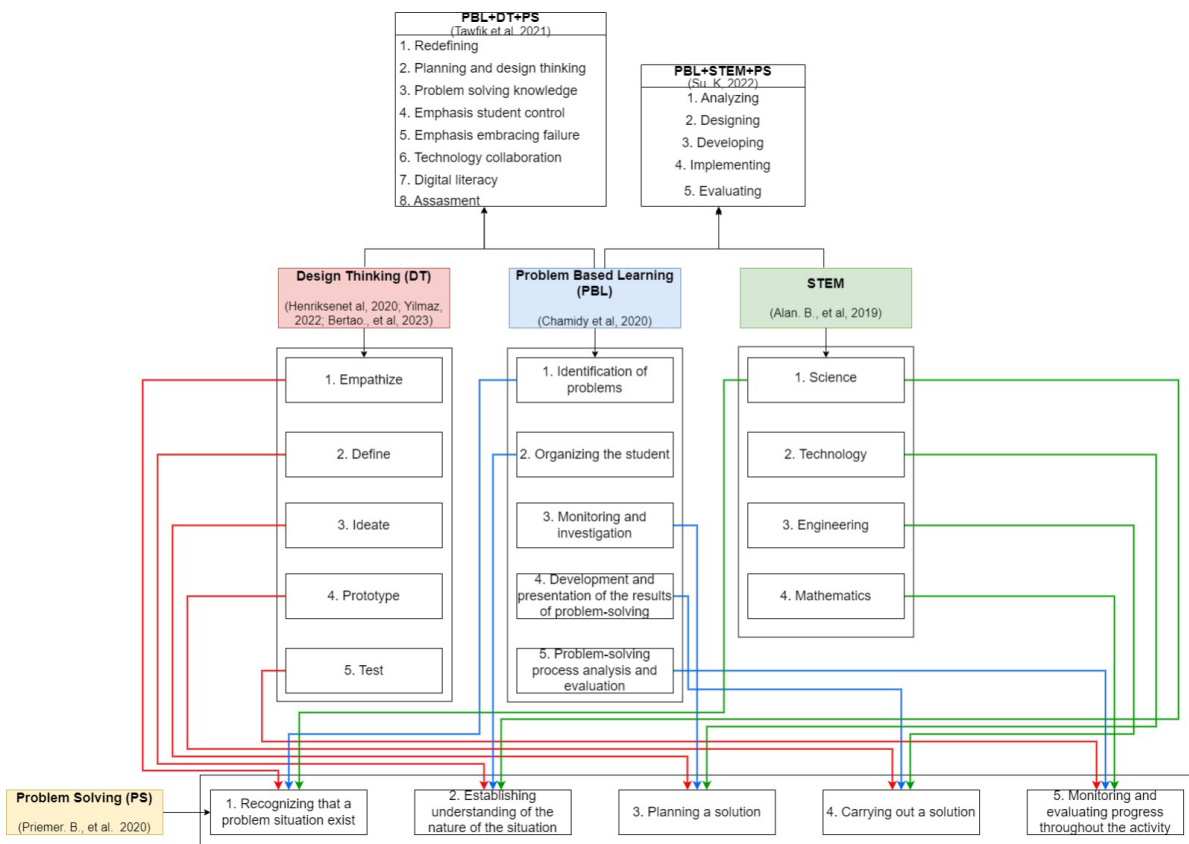


Fig. 6: Framework penelitian pada PBL, DT, STEM terhadap Problem Solving

a deep understanding of the problem and match the conditions of everyday life to better understand and use feelings in understanding the problem. The first stage relates to the problem-solving aspect, namely recognizing that a problem exists. 2) Define: reorganize or redefine the problem according to scientific thinking. The second stage is related to the problem-solving aspect of establishing an understanding of the nature of the situation. 3) Ideate: Each team member has their thoughts (divergent thinking); in this case, the team must narrow down each thought related to existing solutions (convergent thinking). These two thoughts will produce a creative solution to the problem. The third stage relates to the problem-solving aspect of planning a solution. 4) Prototype: The solution obtained based on the results of each member's ideas will be realized in the form of a prototype. The fourth stage is related to the problem-solving aspect of carrying out the solution. 5) Test: After the prototype is made, it will be taken for testing. The prototype from each team will be given input and feedback, and then each team will refine and complete the prototype. The fifth stage is related to the problem-solving aspect of monitoring and evaluating progress throughout the activity. Research by Alan B. et al. (2019) related to STEM learning using disciplines: 1) Science: when prospective teachers are faced with a program and must explore/get to know the program in the field of science. In science, disciplines are related to problem-solving aspects, namely recognizing that a problem situation exists and establishing an understanding of the nature of the situation. 2) Technology: Most of them still need to improve their ability to operate a technological tool, and when problems arise, they help each other to find solutions. In the discipline of technology, it is related to the problem-solving aspect of planning a solution. 3) Engineering: Together with the team, study the program and find out the correct concept so that everything is clear in the future. In engineering, it relates to the problem-solving aspect of carrying out solutions 4) Mathematics: adjusting features to run as expected, then evaluating so that features run more perfectly with mathematical calculations. In the discipline of mathematics, it is related to the problem-solving aspect of monitoring and evaluating

progress throughout the activity. Based on the explanation above, problem-based learning, design thinking, and STEM separately can empower problem-solving skills, as evidenced in each stage as being sustainable with problem-solving aspects. In addition to research separately, research conducted jointly has been carried out, namely PBL+DT on Problem-solving (Tawfik et al., 2021). The stages used the design thinking method in PBL learning to improve problem-solving skills. PBL+STEM research on problem-solving (Su, K, 2022) uses the stages of Analyzing, designing, developing, implementing, and evaluating. PBL+ DT and PBL+STEM research on problem-solving are all sustainable problem-solving (Priemer et al., 2020). In research in higher education, joint research between DT+STEM has yet to be conducted; this is supported in Figure 4 that the topic of DT +STEM is a new topic that is still being developed today. In addition, the simultaneous integration of PBL+DT+STEM on problem-solving has yet to be done simultaneously.

CONCLUSION

Based on the formulation of the problem and the results of the discussion, it can be concluded: 1) The United States is the country that publishes the most articles and has the most influence on PBL, DT, and STEM research on Problem-Solving. The United States also has the most research collaborations. 2) Research related to PBL topics developed the most in 2020 on the topic of STEM, DT to PS developed in 2021, and the integration of PBL, DT, and STEM topics continues to develop until now and is a topic that is still widely researched. 3) In research on the topics of PBL, DT, and STEM in universities, research related to these topics continues to experience an increase every year. Indonesia has the most research articles on the integration of PBL, DT, STEM, and PS topics in higher education. The most widely used research method is quantitative research, which aims to improve the professionalism of prospective teachers from various disciplines. The most widely used instruments in research are test instruments and questionnaires. 4) The integration research of the three topics of PBL, DT, and STEM has never been researched simultaneously, especially for Problem-Solving empowerment. These topics are also constructivist and cognitivist

learning, so they can improve and train problem-solving that is packaged with multidisciplinary. The research framework of PBL, DT, and STEM can be proven to empower problem-solving skills, whether implemented separately or together. These findings will provide a better understanding of the state of PBL, DT, STEM research on Problem Solving and hopefully inform future research ideas

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REFERENCES

1. Abesadze, S., & Nozadze, D. (2020). Make 21st Century Education: The Importance of Teaching Programming in Schools. *International Journal of Learning*, 6(3), 158-163. <https://doi.org/10.18178/IJLT.6.3.158-163>
2. Ahdhianto, E., & Istiq'faroh, N. (2020). The Effect of Problem-Based Learning Models on Mathematical Problem Solving Skills in Primary Schools. *Journal of Xi'an University of Architecture & Technology*, XII(VIII), 165-171.
3. Ahdhianto, E., Marsigit, Haryanto, & Nurfauzi, Y. (2020). Improving fifth-grade students' mathematical problem-solving and critical thinking skills using problem-based learning. *Universal Journal of Educational Research*, 8(5), 2012-2021. <https://doi.org/10.13189/ujer.2020.080539>
4. Alan, B., Zengin, F. K., & Keçeci, G. (2019). Using stem applications for supporting integrated teaching knowledge of pre-service science teachers. *Journal of Baltic Science Education*, 18(2), 158-170. <https://doi.org/10.33225/jbse/19.18.158>
5. Alfaiz, F. S., Pease, R., & Maker, C. J. (2020). Culturally Responsive Assessment of Physical Science Skills and Abilities: Development, Field Testing, Implementation, and Results. *Journal of Advanced Academics*, 31(3), 298-328. <https://doi.org/10.1177/1932202X20920572>
6. Amanda, F. F., Sumitro, S. B., Lestari, S. R., & Ibrohim. (2022). The Correlation of Critical Thinking and Concept Mastery to Problem-Solving Skills: The Role of Complexity Science-Problem Based Learning Model. *Pedagogika*, 146(2), 80-94. <https://doi.org/10.15823/p.2022.146.4>
7. Ananda, R. (2019). The Effect of Learning Strategies and Learning Independence on Learning Outcomes in Learning Evaluation Subject. *IJLRES-International Journal on Language, Research, and Education Studies*, 3(3), 340-350. <https://doi.org/10.30575/2017/IJLRES-2019091201>
8. Araiza-Alba, P., Keane, T., Chen, W. S., & Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Computers and Education*, 164(July 2020), 104121. <https://doi.org/10.1016/j.compedu.2020.104121>
9. Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(3), 857-871. <https://doi.org/10.12973/eurasia.2017.00647a>
10. Asogwa, U., Duckett, T. R., Malefyt, A. P., Stevens, L., Mentzer, G., & Liberatore, M. W. (2021). Comparing engineering problem-solving ability and problem difficulty between textbook and student-written youtube problems. *International Journal of Engineering Education*, 37(5), 1414-1428.
11. Aydin-Gunbatar, S., Tarkin-Celikkiran, A., Kutucu, E. S., & Ekiz-Kiran, B. (2018). The influence of a design-based elective STEM course on pre-service chemistry teachers' content knowledge, STEM conceptions, and engineering views. *Chemistry Education Research and Practice*, 19(3), 954-972. <https://doi.org/10.1039/c8rp00128f>
12. Balakrishnan, B. (2022). Exploring the impact of design thinking tool among design undergraduates: a study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, 32(3), 1799-1812. <https://doi.org/10.1007/s10798-021-09652-y>
13. Bertão, R. A., Jung, C. H., Chung, J., & Joo, J. (2023). Design thinking: A customized blueprint

- to train R & D personnel in creative problem-solving. *Thinking Skills and Creativity*, 48(February). <https://doi.org/10.1016/j.tsc.2023.101253>
14. Bistulfi, G. (2021). Pushing active learning into assessment with a genetics escape-room final: Gamification to develop team skills in STEM, on ground and online. *Journal of Higher Education Theory and Practice*, 21(11), 73-85. <https://doi.org/10.33423/jhetp.v21i11.4665>
 15. Bornmann, L., & Leydesdorff, L. (2014). Scientometrics in a changing research landscape. In *Science & Society* (Vol. 15, Issue 12).
 16. Braun, I., Langner, A., & Graulich, N. (2022). Let's draw molecules: Students' sequential drawing processes of resonance structures in organic chemistry. *Frontiers in Education*, 7(December), 1-24. <https://doi.org/10.3389/feduc.2022.1055280>
 17. Calavia, M. B., Blanco, T., & Casas, R. (2021). Fostering creativity as a problem-solving competence through design: Think-Create-Learn, a tool for teachers. *Thinking Skills and Creativity*, 39(November 2020). <https://doi.org/10.1016/j.tsc.2020.100761>
 18. Carriger, M. S. (2016). What is the best way to develop new managers? Problem-based learning vs. lecture-based instruction. *International Journal of Management Education*, 14(2), 92-101. <https://doi.org/10.1016/j.ijme.2016.02.003>
 19. Chamidy, T., Degeng, I. N. S., & Ulfa, S. (2020). The effect of problem-based learning and tacit knowledge on problem-solving skills of students in computer network practice course. *Journal for the Education of Gifted Young Scientists*, 8(2), 691-700. <https://doi.org/10.17478/JEGYS.650400>
 20. Chen, L., Tang, X. J., Chen, X. K., Ke, N., & Liu, Q. (2022). Effect of the BOPPPS model combined with case-based learning versus lecture-based learning on ophthalmology education for five-year paediatric undergraduates in Southwest China. *BMC Medical Education*, 22(1), 1-7. <https://doi.org/10.1186/s12909-022-03514-4>
 21. Chin, D. B., Blair, K. P., Wolf, R. C., Conlin, L. D., Cutumisu, M., Pfaffman, J., & Schwartz, D. L. (2019). Educating and Measuring Choice: A Test of the Transfer of Design Thinking in Problem Solving and Learning. *Journal of the Learning Sciences*, 28(3), 337-380. <https://doi.org/10.1080/10508406.2019.1570933>
 22. Chomiak-Orsa, I., Greczuk, A., Luczak, K., & Smolag, K. (2023). Application of creative problem-solving methods in remote learning. *Bibliometric analysis. Procedia Computer Science*, 225, 3565-3574. <https://doi.org/10.1016/j.procs.2023.10.352>
 23. Chueh, H. E., & Kao, C. Y. (2024). Exploring the impact of integrating problem based learning and agile in the classroom on enhancing professional competence. *Heliyon*, 10(3), e24887. <https://doi.org/10.1016/j.heliyon.2024.e24887>
 24. Clark, R. M., Stabryla, L. M., & Gilbertson, L. M. (2020). Sustainability coursework: student perspectives and reflections on design thinking. *International Journal of Sustainability in Higher Education*, 21(3), 593-611. <https://doi.org/10.1108/IJSHE-09-2019-0275>
 25. Crichton, M., Crichton, H., & Colville, G. (2022). Students' Perceptions of Problem-Based Learning in Multidisciplinary Groups When Seeking to Solve an Engineering Grand Challenge. *Journal of Problem Based Learning in Higher Education*, 10(1), 20-35. <https://doi.org/10.54337/ojs.jpblhe.v10i1.6823>
 26. Darhim, Prabawanto, S., & Susilo, B. E. (2020). The effect of problem-based learning and mathematical problem posing in improving student's critical thinking skills. *International Journal of Instruction*, 13(4), 103-116. <https://doi.org/10.29333/iji.2020.1347a>
 27. DeWaters, J., & Kotla, B. (2023). Using an open-ended socio-technical design challenge for entrepreneurship education in a first-year engineering course. *Frontiers in Education*, 8(May), 1-10. <https://doi.org/10.3389/feduc.2023.1198161>
 28. Dmitrenko, N., Dolia, I., & Nikolaeva, S. (2020). Soft skills development of prospective educators by means of problem-based ESP learning. *New Educational Review*, 60, 124-134. <https://doi.org/10.15804/tner.2020.60.2.10>
 29. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133(March), 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>

30. Feehily, R. (2018). Problem-based learning and international commercial dispute resolution in the Indian Ocean. *Law Teacher*, 52(1), 17-37. <https://doi.org/10.1080/03069400.2016.1273457>
31. Fogarty, R. (2009). *How to Integrate The Curricula*. Sage Company.
32. Gil-Doménech, D., Berbegal-Mirabent, J., & Merigó, J. M. (2020). STEM education: A bibliometric overview. *Advances in Intelligent Systems and Computing*, 894, 193-205. https://doi.org/10.1007/978-3-030-15413-4_15
33. Glaze, A. L. (2018). Teaching and learning science in the 21st century: Challenging critical assumptions in post-secondary science. *Education Sciences*, 8(1), 1-8. <https://doi.org/10.3390/educsci8010012>
34. Graesser, A. C., Fiore, S. M., Greiff, S., Andrews-Todd, J., Foltz, P. W., & Hesse, F. W. (2018). Advancing the Science of Collaborative Problem Solving. *Psychological Science in the Public Interest*, 19(2), 59-92. <https://doi.org/10.1177/1529100618808244>
35. Guaman-Quintanilla, S., Everaert, P., Chiluiza, K., & Valcke, M. (2022). Impact of design thinking in higher education: a multi-actor perspective on problem solving and creativity. *International Journal of Technology and Design Education*, 0123456789. <https://doi.org/10.1007/s10798-021-09724-z>
36. Guerra, A., Nørgaard, B., & Du, X. (2023). University Educators' Professional Learning in a PBL Pedagogical Development Programme. *Journal of Problem Based Learning in Higher Education*, 11(1), 36-59. <https://doi.org/10.54337/ojs.jpblhe.v11i1.7375>
37. Gunawan, B., Ratmono, B. M., Abdullah, A. G., Sadida, N., & Kaprisma, H. (2022). Research Mapping in the Use of Technology for Fake ... | 472. *Indonesian Journal of Science & Technology*, 7(3), 471-496.
38. He, W., Yan, J., Wang, C., Liao, L., & Hu, X. (2023). Exploring the impact of the design thinking model on fifth graders' creative self-efficacy, situational interest, and individual interest in STEM education. *Thinking Skills and Creativity*, 50(55), 101424. <https://doi.org/10.1016/j.tsc.2023.101424>
39. Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity*, 26(March), 140-153. <https://doi.org/10.1016/j.tsc.2017.10.001>
40. Hong, Y. C., & Choi, I. (2019). Relationship between student designers' reflective thinking and their design performance in bioengineering project: exploring reflection patterns between high and low performers. *Educational Technology Research and Development*, 67(2), 337-360. <https://doi.org/10.1007/s11423-018-9618-6>
41. Hou, X., Li, R., & Song, Z. (2022). A Bibliometric Analysis of Wicked Problems: From Single Discipline to Transdisciplinarity. In *Fudan Journal of the Humanities and Social Sciences* (Vol. 15, Issue 3). Springer Berlin Heidelberg. <https://doi.org/10.1007/s40647-022-00346-w>
42. Huang, X., Erduran, S., Luo, K., Zhang, P., & Zheng, M. (2022). Investigating in-service teachers' STEM literacy: the role of subject background and gender. *Research in Science and Technological Education*, 00(00), 1-21. <https://doi.org/10.1080/02635143.2022.2153243>
43. Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-Based Learning. In M. D. M. Spector, D. Merrill, J. van Merriënboer (Ed.), *Handbook of research on educational communications and technology* (3rd ed., pp. 485-506). Erlbaum.
44. Khwaengmek, V., & Faikhamta, C. (2023). Perceptions of pre-service science teachers toward teaching STEM from suburb University in Thailand. *Kasetsart Journal of Social Sciences*, 44(1), 223-230. <https://doi.org/10.34044/j.kjss.2023.44.1.25>
45. Kijima, R., & Sun, K. L. (2020). 'Females Don't Need to be Reluctant': Employing Design Thinking to Harness Creative Confidence and Interest in STEAM. *International Journal of Art and Design Education*, 40(1), 66-81. <https://doi.org/10.1111/jade.12307>
46. Léger, M. T., Laroche, A. M., & Pruneau, D. (2020). Using design thinking to solve a local environmental problem in the context of a university civil engineering course - an intrinsic case study. *Global Journal of Engineering Education*, 22(1), 6-12.
47. Leijon, J., Staffas, K., Boström, C., & Bernhoff, H. (2020). Student-centered learning in an engi-

- neering course with project-integrated laboratory experiment. *Hogre Utbildning*, 10(1), 57-62. <https://doi.org/10.23865/hu.v10.2179>
48. Lin, C., & Tu, H. (2021). Problem-based learning and capstone course teaching strategies for university social responsibility: The case of a packaging design course. *International Journal of Learning, Teaching and Educational Research*, 20(5), 249-270. <https://doi.org/10.26803/IJLTER.20.5.14>
49. Liso, V. (2020). Implementing the Introduction, Methods, Results and Discussion Article Structure in Engineering Education based on Problem-Based Learning. *Journal of Problem Based Learning in Higher Education*, 8(2), 61-75. <https://doi.org/10.5278/ojs.jpblhe.v8i2.3366>
50. Liu, T., & Israel, M. (2022). Uncovering students' problem-solving processes in game-based learning environments. *Computers and Education*, 182(June 2021), 104462. <https://doi.org/10.1016/j.compedu.2022.104462>
51. Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the efficacy of problem-based learning in diverse secondary school classrooms: Characteristics and goals of problem-based learning. *International Journal of Educational Research*, 112(October 2021), 101945. <https://doi.org/10.1016/j.ijer.2022.101945>
52. Lu, D., & Xie, Y. N. (2024). The application of educational technology to develop problem-solving skills: A systematic review. *Thinking Skills and Creativity*, 51(May 2023), 101454. <https://doi.org/10.1016/j.tsc.2023.101454>
53. Machmud, M. T., Utami, N. M., Fakhri, M. M., & Mayasari, M. (2023). Analyzing University Students Ill-Structured Problem Solving Ability in Indonesian Educational. *Indonesian Journal of Educational Studies (IJES)*, 26(1), 77-85.
54. Makwakwa, E. G., Mogari, D., & Ogbonnaya, U. I. (2024). First-year undergraduate students' statistical problem-solving skills. *Teaching Statistics*, 46(1), 8-23. <https://doi.org/10.1111/test.12359>
55. Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity*, 27(August 2017), 177-189. <https://doi.org/10.1016/j.tsc.2018.02.004>
56. Nahdi, D. S., Jatisunda, M. G., Cahyaningsih, U., & Suciawati, V. (2020). Pre-service teacher's ability in solving mathematics problem viewed from numeracy literacy skills. *Elementary Education Online*, 19(4), 1902-1910. <https://doi.org/10.17051/ilkonline.2020.762541>
57. Nguyen, T. P. L. (2023). Integrating circular economy into STEM education: A promising pathway toward circular citizenship development. *Frontiers in Education*, 8(March), 1-9. <https://doi.org/10.3389/feduc.2023.1063755>
58. O'Neill, M., Adams, M. P., Bandelt, M. J., Chester, S. A., Cai, W., & Nadimpalli, S. P. V. (2019). Cohort Learning: Supporting Transdisciplinary Communication and Problem-solving Skills in Graduate STEM Researchers. *International Journal of Teaching and Learning in Higher Education*, 31(1), 166-175.
59. Peters-burton, E. E., & Stehle, S. M. (2019). Developing student 21 st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, 1, 1-15.
60. Phang, F. A., Puspanathan, J., Musa, A., Baharom, M., Rahman, N. F., Arsat, M., & Nawi, N. D. (2019). Framework to develop low carbon society among school community. *International Journal of Recent Technology and Engineering*, 7(6), 773-777. <https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scop=85066735853&origin=inward>
61. Pinter, R., & Cisar, S. M. (2018). Measuring Team Member Performance in Project Based Learning. *Journal of Applied Technical and Educational Sciences*, 8(4), 22-34. <https://doi.org/10.24368/jates.v8i4.56>
62. Prahani, B. K., Rizki, I. A., Nisa, K., Citra, N. F., Alhusni, H. Z., & Wibowo, F. C. (2022). Implementation of Online Problem-Based Learning Assisted By Digital Book With 3D Animations To Improve Student'S Physics Problem-Solving Skills in Magnetic Field Subject. *Journal of Technology and Science Education*, 12(2), 379-396. <https://doi.org/10.3926/jotse.1590>
63. Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rösken-Winter, B., Tiemann, R., & Zu Belzen, A. U. (2020). A framework to foster problem-solving in STEM and computing education. *Research in Sci-*

- ence and Technological Education, 38(1), 105-130. <https://doi.org/10.1080/02635143.2019.1600490>
64. Rahmawati, J., Masykuri, M., & Utomo, S. B. (2025). A systematic literature review and bibliometric analysis of education for sustainable development integration in science education and its unaddressed gaps. *Journal of Environment and Sustainability Education*, 3(4), 561-574. <https://doi.org/10.62672/joease.v3i4.147>
65. Raman, Y., Surif, J., & Ibrahim, N. H. (2024). The Effect of Problem Based Learning Approach in Enhancing Problem Solving Skills in Chemistry Education: A Systematic Review. *International Journal of Interactive Mobile Technologies*, 18(5), 91-111. <https://doi.org/10.3991/ijim.v18i05.47929>
66. Rao, H., Puranam, P., & Singh, J. (2022). Does design thinking training increase creativity? Results from a field experiment with middle-school students. *Innovation: Organization and Management*, 24(2), 315-332. <https://doi.org/10.1080/14479338.2021.1897468>
67. Ratminingsih, N. M., Gede Budasi, I., Piscayanti, K. S., Putu, N. L., Adnyayanti, E., Novita, I. G. A. P., & Paragae, S. (2021). 4C-Based Learning Model: What, Why, How? *Jurnal Pendidikan Indonesia (JPI)*, 10(2), 244-255. <https://doi.org/10.23887/jpi-undiksha.v10i2.31400>
68. Rehmat, A. P., & Hartley, K. (2020). Building engineering awareness: Problem-based learning approach for STEM integration. *Interdisciplinary Journal of Problem-Based Learning*, 14(1), 1-15. <https://doi.org/10.14434/ijpbl.v14i1.28636>
69. Rofik, A., Setyosari, P., Effendi, M., & Sulito. (2022). The Effect of Collaborative Problem Solving & Collaborative Project-Based Learning Models to Improve The Project Competences of Pre-Service Teachers. *Pegem Egitim ve Ogretim Dergisi*, 12(3), 130-143. <https://doi.org/10.47750/pegogog.12.03.15>
70. Şahin, E., Sarı, U., & Şen, Ö. F. (2024). STEM professional development program for gifted education teachers: STEM lesson plan design competence, self-efficacy, computational thinking and entrepreneurial skills. *Thinking Skills and Creativity*, 51, 101439. <https://doi.org/https://doi.org/10.1016/j.tsc.2023.101439>
71. Salgado-Chavarría, D., & Palacios-Alquisira, J. (2021). Problem-based Learning Approach to Review the Green Chemistry Principles When Applied to a Polycondensation Reaction. *Science Education International*, 32(2), 107-113. <https://doi.org/10.33828/sei.v32.i2.3>
72. Sari, U., Alici, M., & Sen, Ö. F. (2018). The Effect of STEM Instruction on Attitude, Career Perception and Career Interest in a Problem-based Learning Environment and Student Opinions. *Electronic Journal of Science Education*, 22(1), 1-21.
73. Scholkmann, A., Stegeager, N., & Miller, R. K. (2023). Integrating the Integration: The Role and Challenges of Problem-Based Learning in Bringing Together Social Science and Humanities (SSH) and Science, Technology, Engineering and Mathematics (STEM). *Journal of Problem Based Learning in Higher Education*, 11(1), 98-123. <https://doi.org/10.54337/ojs.jpblhe.v11i1.7371>
74. Shidiq, A. S., Huda, Z. Z., Yamtinah, S., Ulfa, M., Masykuri, M., & Saputro, A. N. C. (2025). Inquiry based experiments to enhance sustainability literacy: A systematic literature review and bibliometric analysis. *Journal of Environment and Sustainability Education*, 3(2), 287-303. <https://doi.org/10.62672/joease.v3i2.98>
75. Soysal, Y. (2022). Science Curriculum Objectives' Intellectual Demands: A Thematic Analysis. *Journal of Science Learning*, 5(1), 127-140. <https://doi.org/10.17509/jsl.v5i1.35439>
76. Sri Suryanti, H. H., & Supeni, S. (2019). A problem based learning (PBL) model in developing students' soft skills aspect. *International Journal of Higher Education*, 8(8), 62-69. <https://doi.org/10.5430/ijhe.v8n8p62>
77. Stubbs, E. A., Zimmerman, A. R., Warner, L. A., & Myers, B. E. (2018). Reflecting on a multidisciplinary collaboration to design a general education climate change course. *Journal of Environmental Studies and Sciences*, 8(1), 32-38. <https://doi.org/10.1007/s13412-017-0451-8>
78. Su, K. D. (2022). The Effects of Cross-Disciplinary Life Science Innovation Implemented By Students' Stimulated Strategies for Pbl-Stem Self-Efficacy. *Journal of Baltic Science Education*, 21(6), 1069-1082. <https://doi.org/10.33225/jbse/22.21.1069>

79. Susbiyanto, S., Kurniawan, D. A., Perdana, R., & Riantoni, C. (2019). Identifying the mastery of research statistical concept by using problem-based learning. *International Journal of Evaluation and Research in Education*, 8(3), 461-469. <https://doi.org/10.11591/ijere.v8i3.20252>
80. Tawfik, A. A., Gish-Lieberman, J. J., Gatewood, J., & Arrington, T. L. (2021). How K-12 Teachers Adapt Problem-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, 15(1). <https://doi.org/10.14434/ijpbl.v15i1.29662>
81. Thi-Huyen, N., Xuan-Lam, P., & Thanh Tu, N. T. (2021). The Impact of Design Thinking on Problem Solving and Teamwork Mindset in A Flipped Classroom. *Eurasian Journal of Educational Research*, 2021(96), 30-50. <https://doi.org/10.14689/ejer.2021.96.3>
82. Toker, S., & Akbay, T. (2022). A comparison of recursive and nonrecursive models of attitude towards problem-based learning, disposition to critical thinking, and creative thinking in an computer literacy course for preservice teachers. In *Education and Information Technologies* (Vol. 27, Issue 5). Springer US. <https://doi.org/10.1007/s10639-022-10906-y>
83. VanGronigen, B. A., Bailes, L. P., & Saylor, M. L. (2023). "Stuck in this wheel": The use of design thinking for change in educational organizations. *Journal of Educational Change*, 24(4), 699-725. <https://doi.org/10.1007/s10833-022-09462-6>
84. Vidad, D. C., & Quimbo, M. A. T. (2021). Students' problem-solving difficulties and coping strategies in mathematics: A model-building study. In *International Journal of Learning, Teaching and Educational Research* (Vol. 20, Issue 9). <https://doi.org/10.26803/ijlter.20.9.9>
85. Wang, C. C. (2021). The process of implementing problem-based learning in a teacher education programme: an exploratory case study. *Cogent Education*, 8(1). <https://doi.org/10.1080/2331186X.2021.1996870>
86. Wynn, C. (2022). Facilitating Postformal Thinking Through Problem-Based Learning in the History Survey Course: An Empirically Tested PBL Model. *Journal of Problem Based Learning in Higher Education*, 10(1), 121-133. <https://doi.org/10.54337/ojs.jpblhe.v10i1.7288>
87. Yalçın, V. (2022). Design-Oriented Thinking in STEM education: Exploring the Impact on Preschool Children's Twenty-First-Century Skills. *Science & Education*, 0123456789. <https://doi.org/10.1007/s11191-022-00410-7>
88. Yalçın, V., & Erden, Ş. (2021). The Effect of STEM Activities Prepared According to the Design Thinking Model on Preschool Children's Creativity and Problem-Solving Skills. *Thinking Skills and Creativity*, 41(February). <https://doi.org/10.1016/j.tsc.2021.100864>
89. Yang, C. M., & Hsu, T. F. (2020). Integrating design thinking into a packaging design course to improve students' creative self-efficacy and flow experience. *Sustainability (Switzerland)*, 12(15). <https://doi.org/10.3390/SU12155929>
90. Yilmaz, G. (2022). Revitalizing the communication classroom: A case of design thinking. *Communication Teacher*, 36(3), 216-233. <https://doi.org/10.1080/17404622.2021.1962934>
91. Zhan, Z., Shen, W., Xu, Z., Niu, S., & You, G. (2022). A bibliometric analysis of the global landscape on STEM education (2004-2021): towards global distribution, subject integration, and research trends. *Asia Pacific Journal of Innovation and Entrepreneurship*, 16(2), 171-203. <https://doi.org/10.1108/apjie-08-2022-0090>
92. Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (STEM) across genders and grade levels. *Journal of Baltic Science Education*, 18(3), 466-480. <https://doi.org/10.33225/jbse/19.18.466>
93. Zimmerman, R. H., Maker, C. J., & Alfaiz, F. (2020). Culturally Responsive Assessment of Life Science Skills and Abilities: Development, Field Testing, Implementation, and Results. *Journal of Advanced Academics*, 31(3), 329-366. <https://doi.org/10.1177/1932202X20923981>