

A Bibliometric Analysis of Complex Problem-Solving Approaches in Engineering Education

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Abstract

The evolving landscape of engineering education requires the development of advanced cognitive skills, particularly complex problem-solving (CPS). As engineering challenges grow in complexity, CPS has become a vital competency. However, research on CPS in engineering education remains scattered. This study presents a systematic bibliometric analysis to uncover trends, key contributors, and thematic focuses in CPS-related research. Using the Scopus database and VOSviewer 1.6.20, the study analyzed publications based on co-authorship, co-citation, and keyword co-occurrence. The five-stage bibliometric approach by Masitoh et al. (2021) and Bukar et al. (2023) was adopted, encompassing keyword selection, data retrieval, screening, analysis, and visualization. Findings show a notable rise in CPS publications after 2010, peaking between 2022 and 2024. Dominant keywords include “active learning,” “simulation,” “artificial intelligence,” and “project-based learning,” indicating a shift toward AI-driven, technology-enhanced approaches. China, the United States, and India lead in research output, reflecting global efforts in reforming engineering education. The study highlights the growing emphasis on interdisciplinary and problem-based learning. Despite this momentum, regional disparities remain. Insights from this analysis are valuable for curriculum developers, educators, and policymakers to enhance CPS integration and guide future research toward more holistic and inclusive approaches.

Keywords: Bibliometric Analysis; Complex Problem-Solving; Complex Engineering Problem Solving; Engineering Education, Research Trends

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1. Introduction

The rapid evolution of engineering disciplines necessitates the development of advanced cognitive skills, particularly complex problem-solving (CPS), which is integral to academic and professional success (H. Wu & Molnár, 2022). While traditional engineering education emphasizes technical skills, there is now an increasing demand for cognitive flexibility, interdisciplinary thinking, and real-world problem-solving capabilities (Mohd Matore et al., 2018). CPS involves identifying, analyzing, and resolving unfamiliar, dynamic, and multifaceted problems through logical reasoning. It includes two main phases: knowledge acquisition and knowledge application (Funke, 2001; Novick & Bassok, 2005). The development of CPS skills is closely linked with metacognitive abilities, as students who monitor and regulate their cognitive processes tend to perform better in solving complex, unfamiliar problems (Utami et al., 2023).

To cope with increasingly intricate engineering challenges, CPS integration into curricula has become essential to strengthen conceptual understanding and practical competencies (H. Wu & Molnár, 2022). The demands of Industrial Revolutions 4.0 and 5.0 further push for CPS approaches that include artificial intelligence (AI), automation, and human-centered innovations. The World Economic Forum (WEF) emphasizes CPS as a vital skill for future engineers to remain competitive, adaptable, and solution-oriented (WEF 2023, 2025). Furthermore, CPS is a key element of the Washington Accord’s graduate attributes for internationally recognized engineers (Hassan et al., 2022). This necessitates the inclusion of authentic, competency-based, and personalized assessments in engineering curricula (Garay-Rondero et al., 2024).

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Inductive reasoning (IR) and combinatorial reasoning (CR) are vital strategies that enable students to analyze variable relationships and devise practical solutions (H. Wu & Molnár, 2022). Structured reasoning approaches have been shown to enhance CPS performance significantly (Molnár & Csapó, 2018), especially when combined with hypothesis testing and systematic trial-and-error strategies (Alrababah et al., 2024).

Bibliometric analysis has emerged as a methodical approach to evaluate CPS-related research trends, identify influential publications, and map theoretical frameworks. However, existing literature remains fragmented. This study conducts a comprehensive bibliometric analysis of CPS in engineering education, focusing on recent publications to ensure findings reflect the most current developments. Limiting the scope temporally allows for a manageable and relevant analysis. Despite growing attention to CPS, implementation across educational contexts varies. Regional differences in curriculum design, assessment practices, and CPS familiarity create inconsistencies in performance outcomes (Alrababah et al., 2024; H. Wu & Molnár, 2022). While Western institutions often use standardized simulations and digital tools, others, particularly in Asia and the Middle East, are still developing structured CPS assessments. Technological tools like the MicroDYN framework now allow educators to assess knowledge acquisition (KAC) and knowledge application (KAP) more accurately, giving insight into students' problem-solving processes (Greiff, 2017; Schweizer et al., 2013). Additionally, collaborative problem-solving (CoPS) has proven effective in enhancing analytical thinking through peer interaction (Guo et al., 2023).

Given these complexities, this study systematically explores the bibliometric landscape of CPS research within engineering education by addressing the following research questions: (1) What are the emerging trends in complex problem-solving in engineering education research based on publication years?, (2) What are the most frequently used keywords associated with complex problem-solving in engineering education studies?, (3) Which authors and countries contribute the most to publications in this research area?, and (4) Which countries contribute the most to publications in this research area?

Using bibliometric tools, this study identifies popular keywords to streamline the vast literature and map relationships between different research areas, uncovering how various aspects of CPS are interconnected. Additionally, analyzing publications by country reveals the global distribution of research output, highlighting international collaborations and networks. This is particularly relevant in engineering education, where cultural and regional contexts may influence research perspectives and outcomes. Mapping authorship and collaborations by country provides valuable insights for new researchers seeking partnerships and established researchers aiming to expand their collaborative reach. By addressing these aspects, this study aims to provide a comprehensive overview of the intellectual structure, influential publications, and evolving research frontiers in CPS within engineering education. The findings will inform the development of more effective instructional strategies and highlight regional strengths and gaps in the global research landscape.

2. Research Methods

This study employed a bibliometric approach to systematically map the research landscape of CPS approaches in engineering education, with Scopus serving as the primary source of bibliographic metadata. Bibliometrics involves aggregating, organizing, and analyzing bibliographic data derived from scientific publications, offering both descriptive insights (e.g., publication trends, authorship patterns) and advanced methodologies such as co-citation analysis and keyword co-occurrence mapping. This method has been widely used across disciplines, including health sciences, social sciences, and education (Ishak et al., 2025; Lima & Ribeiro, 2023; Verbeek et al., 2002; Wu & Wu, 2017; Zhang et al., 2024).

The Scopus database was selected for its comprehensive coverage of peer-reviewed sources, including journal articles, conference proceedings, and book chapters (Masitoh et al., 2021; Hernández-Torrano & Ibrayeva, 2020; Ishak et al., 2025; Sabtu & Mohd Matore, 2024; Masdoki et al. 2021). Since its launch by Elsevier in 2004, Scopus has indexed more than 49 million records across 29,200 titles from over 7,000 publishers worldwide (Falagas et al., 2008; Kulkarni et al., 2009), encompassing a broad range of subject areas. Moreover, it provides key bibliometric metrics such as citation counts, h-index scores, and author affiliations, enabling in-depth analysis (Masitoh et al., 2021; Ishak et al., 2025). To achieve the study's objectives, a five-step bibliometric analysis framework in figure 1 was adapted from Masitoh et al. (2021) and Bukar et al. (2023). The first step, Defining Search Keywords, involved identifying relevant terms associated with CPS and engineering education. Boolean operators (AND, OR, NOT) were applied to construct precise search queries. During the Initial Search Result phase, targeted queries were executed within the Scopus database. The Refinement of Search Results followed, applying inclusion and exclusion criteria to filter out irrelevant records. In the fourth step, Compiling Initial Data Statistics, descriptive analysis was conducted to examine publication

trends, active contributors, and country-wise distribution. The final step, Data Analysis, was facilitated by VOSviewer version 1.6.20, which supported visual mapping of co-authorship networks, keyword co-occurrence, and citation linkages. This helped to reveal thematic clusters, research gaps, and collaborative patterns (Fahimnia et al., 2015). The study adopted a quantitative bibliometric approach to capture trends and thematic development in CPS research. VOSviewer’s visualization capabilities were particularly useful for identifying influential research topics and author networks. Repetition of the five-step method across both versions of the methodology—whether referencing CPS alone or incorporating complex engineering problems (CEP)—ensured consistency and reliability.

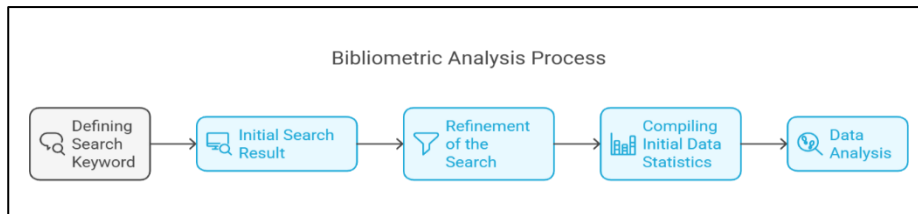


Fig. 1. The Five Steps in Bibliometric Analysis adopted by Ari Masitoh et al. (2021).

2.1. Data Search Strategy

Table 1 presents the variations of search terms and corresponding category labels used in this study. A systematic approach was employed to ensure a robust and comprehensive analysis of the existing body of knowledge on CPS approaches in engineering education. The search strategy incorporated Boolean operators and specific keywords to capture publications aligned with the research scope while minimizing irrelevant results.

Table 1. Search string and category labels

Term	Variations	Category Labels
Complex Problem Solving	“Complex Problem Solving” AND “Engineering”	CPS_E
Complex Engineering Problem	“Complex Engineering Problem Solving” OR “Complex Engineering Problem”	CEPS_CEP

The search terms were carefully selected to reflect the core themes of complex problem-solving in engineering education, ensuring alignment with the research questions. This approach follows the bibliometric methodologies outlined by Donthu et al. (2021), emphasizing the importance of precise search terms to avoid redundancy and enhance the accuracy of the retrieved datasets (Donthu et al. 2021).

2.2. Initial Search Results

Table 2 presents the search algorithms and the number of documents retrieved under each search category. As expected, the literature on CPS in engineering education was broader than specific subdomains like complex engineering problems and curriculum-based studies. This aligns with the research objectives of identifying trends, keywords, and key contributors in the field.

Table 2. Document retrieval results by search category

Search category label	Algorithms	Number of finding documents
CPS_E	TITLE-ABS-KEY (“complex problem solving” AND “engineering”) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , “ENG”) OR LIMIT-TO (SUBJAREA , “COMP”) OR LIMIT-TO (SUBJAREA , “SOCI”) OR LIMIT-TO (SUBJAREA , “MATH”) OR LIMIT-TO (SUBJAREA , “PSYC”) OR LIMIT-TO (SUBJAREA , “DECI”) OR LIMIT-TO (SUBJAREA , “ENVI”) OR LIMIT-TO (SUBJAREA , “ENER”) OR LIMIT-TO (SUBJAREA , “PHYS”) OR LIMIT-TO (SUBJAREA , “MATE”) OR LIMIT-TO (SUBJAREA , “MULT”) OR LIMIT-TO (248

CEPS_CEP	SUBJAREA , “CHEM”) OR LIMIT-TO (SUBJAREA , “CENG”) OR LIMIT-TO (SUBJAREA , “AGRI”) OR LIMIT-TO (SUBJAREA , “EART”)) TITLE-ABS-KEY (“complex engineering problem solving” OR “complex engineering problem”) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , “ENGI”) OR LIMIT-TO (SUBJAREA , “COMP”) OR LIMIT-TO (SUBJAREA , “MATH”) OR LIMIT-TO (SUBJAREA , “SOCI”) OR LIMIT-TO (SUBJAREA , “PHYS”) OR LIMIT-TO (SUBJAREA , “MATE”) OR LIMIT-TO (SUBJAREA , “ENER”) OR LIMIT-TO (SUBJAREA , “ENVI”) OR LIMIT-TO (SUBJAREA , “DECI”) OR LIMIT-TO (SUBJAREA , “CENG”) OR LIMIT-TO (SUBJAREA , “MULT”) OR LIMIT-TO (SUBJAREA , “AGRI”) OR LIMIT-TO (SUBJAREA , “CHEM”) OR LIMIT-TO (SUBJAREA , “PSYC”))	978
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Analysis revealed that documents from the CPS_E and CEPS_CEP categories were mostly aggregated under the broader CPS_C category. This enabled a more focused exploration of publications relevant to complex problem-solving in engineering education. The approach follows bibliometric practices by Donthu et al. (2021), who emphasized refining categories to reduce redundancy and ensure clarity. Gandasari et al. (2024) also highlighted that thematic clustering improves the precision of bibliometric outcomes.

The analysis thus concentrated on documents from the core categories (CPS_E and CEPS_CEP), ensuring alignment with the study's aims. The next sections offer comparative insights into publication timelines, subject areas, and regional origins. This method reflects Bukar et al.'s (2023) guidelines on systematic data handling to extract meaningful insights from bibliometric datasets.

3. Results and Discussion

The bibliometric analysis offers important insights into the research landscape of complex problem-solving (CPS) in engineering education. By analyzing publication trends, keyword co-occurrence, and author and country contributions, the study uncovers evolving research frontiers and intellectual structures in the field. Findings show a growing focus on CPS methodologies, especially in line with Industry 4.0 and 5.0 developments, where AI, computational tools, and interdisciplinary strategies are increasingly embedded in engineering curricula. Research productivity has expanded over the last two decades, with notable contributions from both established and emerging institutions. The following discussion elaborates on these findings in relation to the study's objectives, highlighting major trends, dominant themes, and influential contributors shaping the direction of CPS research in engineering education.

3.1. Emerging Trends in CPS in Engineering Education Research Based on Publication Years

3.1.1. Publication Years

Figure 2 illustrates the publication trends in CPS within engineering education from 2000 to 2025, using the CPS_E and CEPS_CEP search terms. The bibliometric approach was applied using data from the Scopus database, following methodologies outlined by Masitoh et al. (2021) and Ishak et al. (2025) (Ari Masitoh et al. 2021; Ishak et al. 2025).

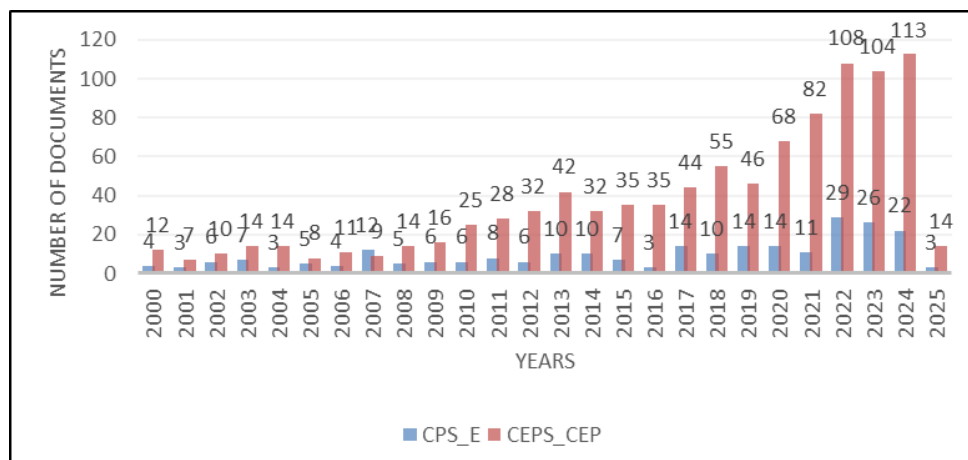


Fig. 2. Annual number of published.

The findings indicate a sharp increase in CPS-related publications, particularly in CEPS_CEP. Before 2010, publications remained below 20 per year, but from 2010 onwards, a noticeable rise occurred, with CEPS_CEP reaching 28 publications in 2011, compared to 8 in CPS_E. The growth became more significant after 2018, where CEPS_CEP increased from 44 publications in 2018 to 113 in 2024, highlighting a strong research focus on complex engineering problems. CPS_E also grew steadily, peaking at 29 publications in 2022, before slightly declining to 22 in 2024. The sharp rise in publications, particularly in the past five years, indicates a growing academic interest in CPS within engineering education. This aligns with the global shift toward incorporating CPS methodologies in problem-based learning and interdisciplinary research (Guo et al. 2023; Veríssimo et al. 2024). The steady upward trend suggests an increasing recognition of CPS as an essential skill in engineering curricula, particularly with the integration of artificial intelligence and computational tools (Nagahi et al. 2021). This analysis aligns with bibliometric methodologies used in previous studies (Lima & Ribeiro 2023; Verbeek et al. 2002; Y. C. J. Wu & Wu 2017), which emphasize how analyzing publication trends helps identify paradigm shifts in a research field.

3.1.2. Subject Areas

The distribution of subject areas across the search categories CPS_E and CEPS_CEP is presented in Figure 3. It is evident that Engineering stands out as the most prominent subject area, with 128 documents under CPS_E and 629 documents under CEPS_CEP, indicating a strong emphasis on complex problem-solving within engineering disciplines. This reflects the growing recognition of CPS as a critical skill set for future engineers. Apart from engineering, Computer Science also emerges as a significant domain, with 106 documents for CPS_E and 415 documents for CEPS_CEP, highlighting the increasing reliance on computational tools and simulations to enhance problem-solving capabilities in engineering education (Ling 2024). Similarly, Mathematics shows considerable representation, with 14 documents under CPS_E and 217 under CEPS_CEP, underscoring the importance of analytical and quantitative skills in tackling complex problems. Other notable subject areas include Social Sciences (96 documents for CPS_E and 118 for CEPS_CEP), Physics and Astronomy (6 and 103 documents, respectively), and Energy (7 and 69 documents). These fields suggest interdisciplinary applications of CPS approaches beyond traditional engineering contexts. Interestingly, the Chemical Engineering, Environmental Science, Decision Sciences, and Materials Science categories exhibit relatively lower outputs, indicating that CPS-related research in these fields is still developing. The dominance of publications within the science and technology fields, compared to limited contributions from commerce and humanities, suggests a strong technical focus in the current literature. This highlights an opportunity for future research to incorporate more diverse perspectives, including economic and social considerations, to achieve a more holistic understanding of complex problem-solving in engineering education (Azmin et al. 2023; M. Zhang & Andersson 2023).

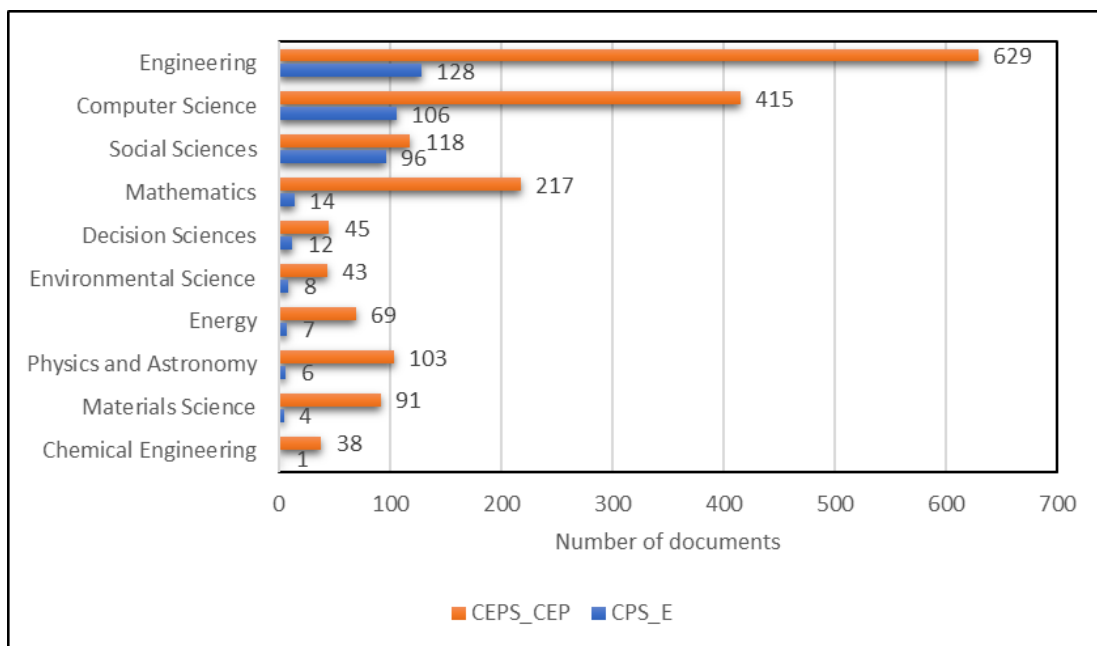


Fig. 3. Subject areas of research field.

3.2. The Most Frequently Used Keywords Associated with Complex Problem-Solving in Engineering Education Studies

3.2.1. Keyword Co-Occurrence Analysis

This bibliometric analysis employed VOSviewer to examine CPS research in engineering education, focusing on co-citation, co-authorship, and keyword co-occurrence networks. The methodology followed the structured network-based bibliometric approach by Donthu et al. (2021), essential for uncovering research trends, collaborative networks, and thematic clusters. To create the keyword co-occurrence map, data were extracted from Scopus using RIS files based on relevant search queries. According to Perianes-Rodriguez et al. (2016), the “Title and Abstract” fields were selected for keyword extraction, using the “Full Counting” method to ensure a comprehensive analysis. A minimum threshold of 10 keyword occurrences yielded 26,128 initial terms, of which 695 met the criteria. After manual verification, 417 relevant keywords were retained.

Following Wulandari (2024), appropriate thresholds were applied to include significant terms while filtering out less relevant ones. The co-occurrence map revealed two major thematic clusters in CPS research. The first cluster (red nodes) reflected technical and computational aspects, with frequent keywords such as “algorithm,” “parameter,” “simulation,” and “efficiency,” indicating a focus on computational problem-solving. The second cluster (green nodes) centered on pedagogical and cognitive elements, with terms like “student,” “education,” and “practice,” emphasizing instructional strategies.

Density visualization offered further insights into emerging trends. High-density (yellow) regions pointed to active research areas, especially at the intersection of computational techniques and student-centered learning. This observation aligns with Ishak et al. (2025), who emphasized that network and density maps help reveal the knowledge structure of a field and identify research gaps. As illustrated in Figure 4 and Figure 5, the findings show CPS research is evolving along two main directions: (1) computational problem-solving methods, and (2) pedagogical strategies. Future research should explore how these domains intersect, particularly in designing teaching methods that integrate computational frameworks effectively into engineering education.

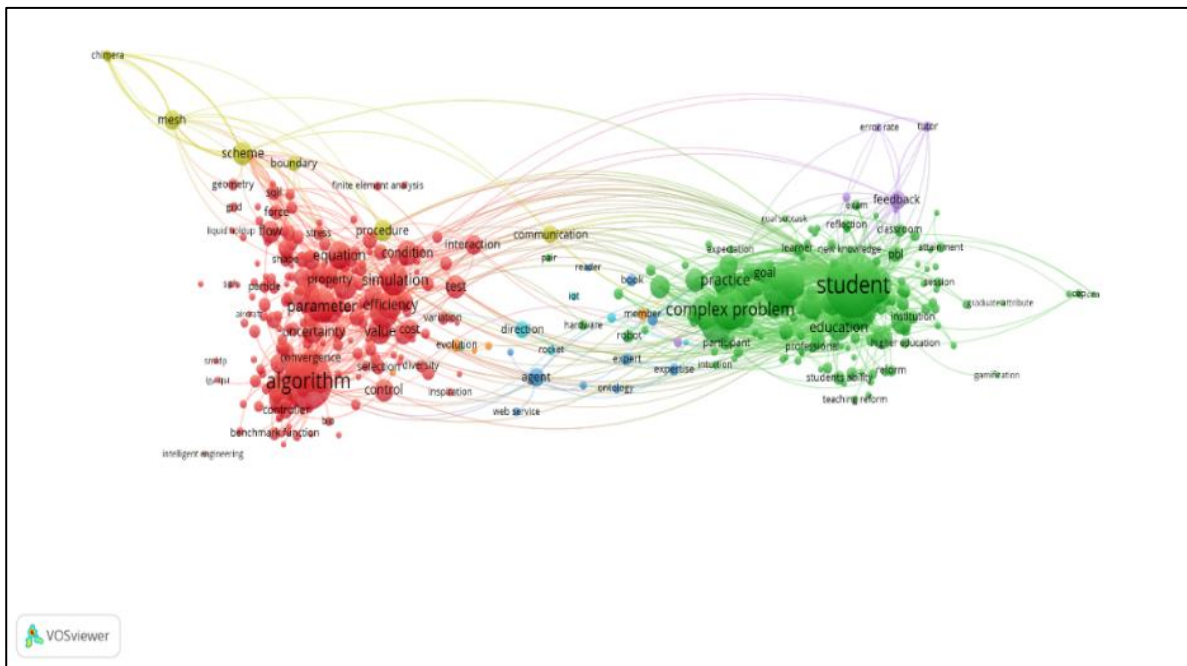


Fig. 4. Network visualization co-occurrence CPS_E and CEPS_CEP.

Special session - Not all problems are created equal: From problem-based learning theory to research on complex problem solving and implications for the engineering classroom	Pierrakos, O., Watson, H., Kander, R. , Russell, J. , Anderson, R.	2010	Proceedings - Frontiers in Education Conference, FIE	19	0.84
Dealing with the uncertainties of climate engineering: Warnings from a psychological complex problem-solving perspective	Amelung, D., Funke, J.	2013	Technology in Society	17	1.43
Project types and complex problem-solving competencies: Towards a conceptual framework	Kolmos, A., Bertel, L.B., Holgaard, J.E. , Routhé, H.W.	2020	International Research Symposium on PBL, pp. 56–65	15	3.59
New curricula for engineering education: Experiences, engagement, e-resources	Jonassen, D.H., Engle, R.W. , Cheng, P.C.-H. , Salas, E.	2017	Global Journal of Engineering Education, pp. 112–117	12	1.20
IDEALS: A model for integrating engineering design professional skills assessment and learning	Davis, D.C., Trevisan, M.S., Davis, H.P.	2011	ASEE Annual Conference and Exposition, Conference Proceedings	11	4.44
Optimization Techniques for Solving Complex Problems	Alba, E., Blum, C., Isasi, P., León, C., Gómez, J.A.	2008	Optimization Techniques for Solving Complex Problems, pp. 1–476	10	0.07
Developing Future Skills in Engineering Education for Industry 5.0: Enabling Technologies in the Age of Digital Transformation and Green Transition	Ciolacu, Monica I., Alves, Gustavo R., Terkowsky, Claudius, Zoubi, Abdallah Y.	2023	Lecture Notes in Networks and Systems 763 LNNS, pp. 1019–1031	9	5.98
Virtual Globalization: An Experience for Engineering Students in the Education 4.0 Framework	Caratozzolo, P., Friesel, A., Randewijk, P.J., Navarro-Duran, D. Liew, C.P.,	2021	ASEE Annual Conference and Exposition, Conference Proceedings	7	2.50
A systematic approach to implementing complex problem solving in engineering curriculum	Hamzah, S.H., Puteh, M. , Mohammad, S. , Badaruzzaman, W.H.W.	2020	Advances in Intelligent Systems and Computing, 1134 AISC, pp. 880–891	7	1.47
The relationships between pre-university education and mathematics achievement with performance in engineering subject	Kamal, N., Arsad, N., Husain, H. , Nopiah, Z.M.	2015	Journal of Engineering Science and Technology, 10(Spec. Issue 2 on UKM Teaching and Learning Congress 2013, May 2015), pp. 10–17	7	1.17
Impact of modelling and simulation in solving complex problems in first year engineering course	Asundi, M., Kandakatla, R. , Joshi, G.	2021	Journal of Engineering Education Transformations	6	0.60
Undergraduate research and complex problem solving: Understanding and translating such experiences to the classroom	Zilberberg, A., Pierrakos, O., Thompson, E.	2010	Proceedings - Frontiers in Education Conference, FIE	5	0.42

3.3.2. Countries with The Highest Research Contributions

The figure 6 illustrates the distribution of scholarly publications on CPS in engineering education across different countries. The data, derived from the Scopus database, highlights the leading contributors to this research domain.

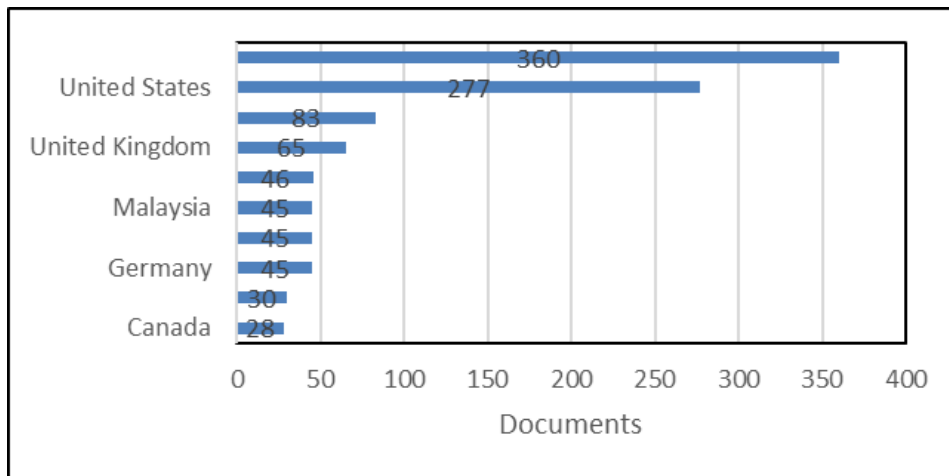


Fig. 6. Trend of research in complex problem-solving in engineering education by country.

China emerges as the dominant contributor, with 360 publications, reflecting its strong emphasis on advancing engineering education through complex problem-solving frameworks. This prominence can be attributed to China's national strategies promoting innovation, technological advancement, and STEM education reform (Zhao, 2021). Following China, the United States accounts for 277 publications, showcasing its longstanding leadership in engineering education research. American institutions, particularly through collaborative efforts between universities and industries, have consistently promoted problem-based learning (PBL) and interdisciplinary approaches to engineering education (Prince & Felder, 2006). India ranks third with 83 publications, indicating its increasing focus on enhancing engineering curricula to equip graduates with critical thinking and complex problem-solving skills (Kumar & Subramanian, 2023). The United Kingdom follows with 65 publications, emphasizing its adoption of digital learning platforms and innovative teaching methodologies in engineering education (Gupta & Thompson, 2022).

Other notable contributors include Iran (46 publications), Malaysia (45 publications), Australia (45 publications), and Germany (45 publications). These countries have actively integrated complex problem-solving frameworks into their educational systems, often supported by national policies and funding initiatives (Ahmad et al., 2022; Fischer et al., 2020). Brazil (30 publications) and Canada (28 publications) round out the list, reflecting their ongoing efforts to strengthen engineering education through CPS-oriented pedagogies (Silva & Pereira, 2021). The chart underscores the global nature of CPS research, with significant contributions from both Western and Eastern nations. The disparity in publication counts highlights varying levels of investment, institutional focus, and national education policies aimed at preparing future engineers for real-world challenges.

The findings from this bibliometric analysis suggest several actionable implications for curriculum designers and educators. The increasing prominence of AI, simulation, and project-based learning highlights the need for engineering programs to embed CPS competencies through authentic learning tasks, such as interdisciplinary design challenges and industry-partnered problem-solving modules. For example, higher education institutions in Malaysia could integrate CPS elements through capstone projects that utilize simulation tools and AI-based platforms. Besides, the CPS competencies can be formed to develop into new instrument that can use different kind of analysis of modern and classical theory as conducted previously in local context (Mohd Matore et al., 2021; Kamaruddin et al., 2021). Additionally, professional development programs for lecturers should emphasize digital pedagogies and assessment strategies aligned with competency-based education. These efforts can enhance students' ability to tackle real-world, ill-structured engineering problems while also supporting national education reforms focused on 21st-century skills.

4. Conclusion

This bibliometric analysis systematically examined CPS research in engineering education by addressing four objectives: (1) identifying emerging trends, (2) analyzing frequently used keywords, (3) determining the most active authors, and (4) identifying contributing countries. Using Scopus and VOSviewer version 1.6.20, this study mapped research patterns, key contributors, and thematic developments. Findings revealed a significant rise in CPS-related publications from 2010, with a sharp surge between 2022 and 2024. This trend highlights the growing global recognition

of CPS as an essential skill in engineering education, aligned with broader STEM reforms and technological innovation. Keyword co-occurrence analysis identified major themes such as "active learning," "simulation," "artificial intelligence," and "project-based learning," marking a shift from traditional cognitive development to AI-enhanced and adaptive learning environments. Emerging terms like "ChatGPT" and "competency-based education" underscore the increasing digitalization of engineering curricula. These changes reflect efforts to better prepare students for complex, real-world engineering challenges. Country-level analysis showed China (360 publications), the United States (277), and India (83) as leading contributors. These countries benefit from strong research ecosystems and policy support for educational innovation. Notably, countries such as the United Kingdom, Malaysia, and Australia also show increasing research output. Malaysia's growing engagement in CPS-related research reflects national efforts to integrate 21st-century skills into its engineering and technical education frameworks. This indicates a broader regional shift toward adopting CPS in curriculum reform and workforce development strategies. This study is not without limitations. First, the bibliometric data were exclusively extracted from the Scopus database, which, although comprehensive, may exclude relevant works indexed in databases such as Web of Science, IEEE Xplore, or Dimensions. Second, only English-language publications were considered, potentially overlooking valuable insights from non-English sources. Third, this study employed a quantitative bibliometric approach without delving into qualitative content analysis. As such, future research could expand by using multi-database comparisons and incorporating qualitative thematic analyses of high-impact publications to provide deeper pedagogical insights.

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References

- Arababah, S.A., Wu, H. & Molnár, G. 2024. A Pilot Study for Measuring Complex Problem-Solving in Jordan: Feasibility, Construct Validity, and Behavior Pattern Analyses. *SAGE Open* 14(2): 1–13. <https://doi.org/10.1177/21582440241249884>.
- Ari Masitoh, P.N., Latifah, S., Saregar, A., Aziz, A., Suharto & Jamaluddin, W. 2021. Bibliometric analysis of physics problem solving. *IOP Conference Series: Earth and Environmental Science* Vol. 1796. <https://doi.org/10.1088/1742-6596/1796/1/012009>.
- Azmin, N.F.M., Mat Isa, C.M., Lee, W.-K., Ibrahim, S.N. & Lian, O.C. 2023. Implementation of Complex Engineering Problem Solving (CEP) and Complex Engineering Activities (CEA) in Malaysian Engineering Curriculum: A Pilot Study. 2023 International Conference on University Teaching and Learning, InCULT 2023. <https://doi.org/10.1109/InCULT59088.2023.10482478>
- Bukar, U.A., Sayeed, M.S., Razak, S.F.A., Yogarayan, S., Amodu, O.A. & Mahmood, R.A.R. 2023. A method for analyzing text using VOSviewer. *MethodsX* 11(102339): 1–19. <https://doi.org/10.1016/j.mex.2023.102339>.
- 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: 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>.
- Fahimnia, B., Sarkis, J. & Davarzani, H. 2015. Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics* 162: 101–114. <http://dx.doi.org/10.1016/j.ijpe.2015.01.003>.
- Falagas, M.E., Pitsouni, E.I., Malietzis, G.A. & Pappas, G. 2008. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. *The FASEB Journal* 22(2): 338–342. <https://doi.org/10.1096/fj.07-94921sf>
- Funke, J. 2001. Dynamic systems as tools for analysing human judgement. *Thinking and Reasoning* 7(1): 69–89. <https://doi.org/10.1080/13546780042000046>

- Gandasari, D., Tjahjana, D., Dwidienawati, D. & Sugiarto, M. 2024. Bibliometric and visualized analysis of social network analysis research on Scopus databases and VOSviewer. *Cogent Business and Management* 11(1): 1–16. <https://doi.org/10.1080/23311975.2024.2376899>.
- Garay-Rondero, C.L., Castillo-Paz, A., Gijón-Rivera, C., Domínguez-Ramírez, G., Rosales-Torres, C. & Oliart-Ros, A. 2024. Competency-based assessment tools for engineering higher education: a case study on complex problem-solving. *Cogent Education* 11(1): 1-31. <https://sci-hub.se/10.1080/2331186X.2024.2392424>
- Greiff, S. 2017. Interactive problem solving: Exploring the potential of minimal complex systems. *The Nature of Problem Solving: Using Research to Inspire 21st Century Learning*. (pp. 93–105). <https://doi.org/10.1787/9789264273955-8-en>
- Greiff, S. & Funke, J. 2009b. Measuring complex problem solving: The MicroDYN approach. Dlm. Scheuermann, F. & Björnsson, J. (pnyt). *The Transition to Computer-Based Assessment. Lessons learned from large-scale surveys and implications for testing* hlm. (pp. 1–8). Office for Official Publications of the European Communities. <http://archiv.ub.uni-heidelberg.de/volltextserver/15502/>.
- Guo, J.W., She, H.C., Chen, M.J. & Tsai, P.Y. 2023. Can CPS better prepare 8th graders for problem-solving in electromagnetism and bridging the gap between high- and low-achievers than IPS? *International Journal of Computer-Supported Collaborative Learning* 18(4): 489–512. <https://doi.org/10.1007/s11412-023-09407-y>
- Hassan, S.A.H.S., Mohd-Yusof, K., Yuan, C.C.C., Phang, F.A., Rahman, N.F.A., Samah, N.A., Zakaria, Z.Y. & binti Ghazali, N.E. 2022. 21st Century Engineering Learning and Teaching: Malaysia Perspective and Direction. *ASEE Annual Conference and Exposition, Conference Proceedings*
- Hernández-Torrano, D. & Ibrayeva, L. 2020. Creativity and education: A bibliometric mapping of the research literature (1975–2019). *Thinking Skills and Creativity* 35(December 2019): 1–17. <https://doi.org/10.1016/j.tsc.2019.100625>.
- Ishak, H., Mohd Matore, M.E.E. & Mohd Nor, H.A.M. 2025. Bibliometric Analysis of Adaptive Behavior Research: Advancing Sustainable Development Goals (SDGS) For Children with Disabilities. *Journal of Lifestyle and SDG'S Review* 5(2): 1–25. <https://doi.org/10.47172/2965-730X.SDGsReview.v5.n02.pe03405>.
- Kamaruddin, M., Mohd Matore, M.E.E. 2021. Development and validation of psychometric properties of the 10 ib learner profile instrument (10iblp-i): A combination of the rasch and classical measurement model. *International Journal of Environmental Research and Public Health*, 2021, 18(12), 6455
- Kulkarni, A. V, Aziz, B., Shams, I. & Busse, J.W. 2009. Comparisons of Citations in Web of Science, *Jama* 302(10): <https://doi.org/1092-1096>. 10.1021/acs.accounts.5b00404.
- Lima, A.A. & Ribeiro, T.D.L.S. 2023. Mapping Sustainable Development Goals Research in Social Sciences: a Bibliometric Analysis. *Journal of Lifestyle and SDG'S Review* 3: 1–23. <https://doi.org/10.37497/2965-730X.SDGsReview.v3.n00.pe01562>
- Ling, J.H. 2024. Implementation of Complex Engineering Problem Solving Projects in a Malaysian Engineering Programme. *Indonesian Journal of Education and Social Science* 3(2): 133–150. <https://ejournal.papanda.org/index.php/ijess> [28 November 2024].
- Masdoki, M., Din, R. & Mohd Matore, M.E.E. 2021. Teaching 4.0 competency in higher learning institutions: A systematic mapping review. *International Journal of Learning, Teaching and Educational Research* 20(10): 217 – 231. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85119328282&doi=10.26803%2Fijlter.20.10.12&partnerID=40&md5=a8c44f7a82b1fc96084e958416c98f83>
- Molnár, G. & Csapó, B. 2018. The efficacy and development of students' problem-solving strategies during compulsory schooling: Logfile analyses. *Frontiers in Psychology* 9(MAR): 1–17. <https://doi.org/10.3389/fpsyg.2018.00302>
- Mohd Matore, M.E.E., Khairani, A. Z., Maat, S.M., Ahmad, N.A. & Mohd Matore, E. R., 2018. The Influence of Intellectual Quotient (IQ), Emotional Quotient (EQ) And Spiritual Quotient (SQ) Against Adversity Quotient (AQ) On Polytechnic Students in Malaysia. *Journal of Engineering Science and Technology Special Issue on ICETVESS* 2017(13): 83–91.

- Mohd Matore, M.E.E., Zainal, M.A., Mohd Noh, M.F., Khairani, A.Z., Abd Razak, N. 2021. The Development and Psychometric Assessment of Malaysian Youth Adversity Quotient Instrument (MY-AQi) by Combining Rasch Model and Confirmatory Factor Analysis. *IEEE Access*, 2021, 9, pp. 13314–13329, 9317780.
- Nagahi, M., Maddah, A., Jaradat, R. & Mohammadi, M. 2021. Development of perceived complex problem-solving instrument in domain of complex systems. *Systems* 9(3): 1–24. <https://doi.org/10.3390/systems9030051>
- Novick, L.R. & Bassok, M. 2005. Problem solving. In K. J. Holyoak & R. G. Morrison (Eds.), *The Cambridge Handbook of Thinking and Reasoning*. Cambridge University Press. <http://books.google.com/books?hl=fr&lr=&id=znbkHaC8QeMC&pgis=1>
- Perianes-Rodriguez, A., Waltman, L. & van Eck, N.J. 2016. Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of Informetrics* 10(4): 1178–1195. <https://doi.org/10.1016/j.joi.2016.10.006>
- Sabtu, S.H. & Mohd Matore, E.E.M. 2024. Systematic literature review on the implementation of the Six Sigma approach in education. *International Journal of Evaluation and Research in Education* 13(1): 262–270. <https://doi.org/10.11591/ijere.v13i1.26196>
- Schweizer, F., Wüstenberg, S. & Greiff, S. 2013. Validity of the MicroDYN approach: Complex problem solving predicts school grades beyond working memory capacity. *Learning and Individual Differences* 24: 42–52. <http://dx.doi.org/10.1016/j.lindif.2012.12.011>.
- Setyaningsih, I. & Jie, F. 2018. Bibliometric analysis of the term “green manufacturing.” *International Journal of Management Concepts and Philosophy* 11(3): 315–339. <https://doi.org/10.1504/ijmcp.2018.10014233>
- Verbeek, A., Debackere, K., Luwel, M. & Zimmermann, E. 2002. Measuring progress and evolution in science and technology – I: The multiple uses of bibliometric indicators. *International Journal of Management Reviews* 4(2): 179–211. <https://doi.org/10.1111/1468-2370.00083>
- Veríssimo, C., Pereira, L., Fernandes, A. & Martinho, R. 2024. Complex problem solving as a source of competitive advantage. *Journal of Open Innovation: Technology, Market, and Complexity* 10(2): 1–23. <https://doi.org/10.1111/1468-2370.00083>
- World Economic Forum. 2023. *Future of Jobs Report 2023: Insight Report*. Cologny/Geneva. <https://www.weforum.org/reports/the-future-of-jobs-report-2023>.
- World Economic Forum. 2025. *Future of Job Report 2025: Insight Report*. Cologny/Geneva. <https://www.weforum.org/reports/the-future-of-jobs-report-2025>.
- Wu, H. & Molnár, G. 2022. Analysing Complex Problem-Solving Strategies from a Cognitive Perspective: The Role of Thinking Skills. *Journal of Intelligence* 10(3). <https://doi.org/10.3390/jintelligence10030046>
- Wu, Y.C.J. & Wu, T. 2017. A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice. *Management Decision* 55(7): 1333–1350. <https://doi.org/10.1108/MD-05-2017-0518>
- Wulandari, W. 2024. Bibliometric analysis of research trends in problem-based learning and problem-solving ability (2002-2022). *International Journal of Studies in Education and Science (IJSES)* 5(1): 13–28. www.ijses.net <https://doi.org/10.46328/ijres.73> <https://doi.org/10.46328/ijres.73>
- Zhang, C., Mohamad, E.M.W., Azlan, A.A. & Qi, Y. 2024. A Bibliometric Analysis of Ehealth Literacy: Evaluating Approaches to Promote Health and Well-Being in the Context of SDGs. *Journal of Lifestyle and SDG'S Review* 4(3): 1–30. <https://doi.org/10.47172/2965-730X.SDGsReview.v4.n03.pe02450>
- Zhang, M. & Andersson, B. 2023. Identifying Problem-Solving Solution Patterns Using Network Analysis of Operation Sequences and Response Times. *Educational Assessment* 28(3): 172–189. <https://doi.org/10.47172/2965-730X.SDGsReview.v4.n03.pe02450>
- Utami, D. D., Setyosari, P., Fajarianto, O., Kamdi, W., & Ulfa, S. (2023). The Correlation Between Metacognitive and Problem-Solving Skills among Science Students. *EduLine: Journal of Education and Learning Innovation*, 3(1), 138–143. <https://doi.org/10.35877/454RI.eduline1702>