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Understanding Engineering Integration in the Engineering Design Process for Science Education: A Sense-Making Bibliometric Analysis

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This bibliometric analysis aims to identify publication trends and key research areas that have shaped studies on the Engineering Design Process (EDP) in science education. A total of 142 highly cited documents published between 2012 and 2025 were retrieved from the Scopus database, accumulating 2,208 citations. The analysis employed biblioMagika® for descriptive bibliometric calculations, OpenRefine and Microsoft Excel for data cleaning, and VOSviewer for network visualization. Beyond standard bibliometric mapping, this study adopts a sense-making approach to interpret the relationships between publication patterns, influential contributors, and emerging research themes, thereby explaining how EDP research has developed conceptually within science education rather than merely reporting numerical trends. The results reveal a steady increase in publications over time, with research output reaching its peak in 2022. Purdue University, Michigan State University, and the University of California were identified as leading institutions. Among individual contributors, Markus Reiser and Luecha Ladachart emerged as key contributing authors. The United States, Germany, and Thailand were the leading contributors to the research output. The major research themes were "engineering design process," "science education," and "design thinking." Overall, the findings suggest that EDP research has evolved into an interdisciplinary field that integrates engineering practices, scientific inquiry, and design-oriented learning within science education.

Keywords: engineering design process, science education, bibliometric analysis, design thinking

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INTRODUCTION

In recent years, there has been a growing emphasis on equipping students with the skills needed to solve complex, real-world problems. The integration of the EDP into STEM education has become increasingly important over the past decade because it promotes interdisciplinary learning (Guzey et al., 2016), critical thinking (Chien et al., 2023) and authentic problem-solving (Syukri et al., 2018). The EDP serves as both a content area and a pedagogical approach that connects scientific inquiry with technological innovation (Krajcik et al., 2014). Studies have demonstrated its role in fostering knowledge transfer (Kelley & Sung, 2017) and supporting collaborative and culturally responsive practices (Brown, 2017). Nevertheless, the literature also emphasizes that these benefits depend greatly on teachers' readiness and instructional capacity for an effective EDP integration (Capobianco et al., 2018). Through EDP, students can develop solutions to identified problem (Atman et al., 2007), justify design choices Crismond & Adams (2012), evaluate outcomes (Dym et al., 2005) and learn from failure during hands-on projects (Pleasants & Olson, 2019). Hence, the EDP encourages deep cognitive engagement beyond surface-level understanding (Yu et al., 2020). However, most existing studies focus primarily on the instructional benefits of EDP at the classroom or intervention level, while giving limited attention to how the field has evolved conceptually, thematically, and disciplinarily over time.

As the EDP has expanded across science and STEM education, it has been recognised as a central mechanism for integrating scientific inquiry with engineering and technological practices. However, despite this rapid proliferation, the literature remains fragmented across disciplines, educational contexts, and conceptual interpretations. The absence of a comprehensive synthesis limits researchers' ability to evaluate how EDP is defined, enacted, and theorised within science education, as well as to understand the roles of engineering and technology in learning. Although previous studies have widely discussed the pedagogical benefits of EDP, they have not systematically examined how the field has evolved in terms of its conceptual structure, thematic development, and disciplinary orientation. To address this gap, this study employs a bibliometric analysis of Scopus-indexed publications from 2012 to 2025 to trace research growth, identify influential works, underexplored areas, and highlight emerging themes within K–12 STEM education. Moving beyond descriptive bibliometric profiling, the analysis integrates performance indicators with science mapping and interpretive synthesis using a sense-making approach (Lim & Kumar, 2024). This technique enables a more nuanced examination of conceptual fragmentation, thematic evolution, and disciplinary orientations of EDP research.

LITERATURE REVIEW

The Engineering Design Process (EDP) has been defined and interpreted in various ways within the broader STEM education movement. Although the term is widely used, the literature does not always conceptualise EDP in the same way. In some studies, the EDP is positioned as a structured problem-solving cycle, while in others it is framed as a design-based pedagogy, a curriculum integration strategy, or a practical activity for applying science and mathematics concepts. Despite these variations, design activity

remains the central feature that distinguishes EDP from other pedagogical approaches. This suggests that EDP is not merely concerned with learning scientific content, but with engaging students in creating, testing, refining, and justifying solutions to authentic problems.

Prior studies have demonstrated the pedagogical value of EDP across different learning contexts. Kelley and Sung (2017), for example, showed that design-centred activities can support sophisticated knowledge transfer, while Crotty et al. (2017) illustrated how robotics-based tasks provide opportunities for students to engage in design, coding, and systems thinking. Other studies have applied EDP through bridge construction (Maeng et al., 2017), renewable energy projects (Abdurrahman et al., 2023), and simple machines (Korur et al., 2017). Collectively, these studies show that EDP is frequently used to contextualise scientific and mathematical concepts through authentic engineering and technological practices. However, they also reveal that EDP implementation varies considerably across topics, tools, and classroom settings.

This variation points to a deeper conceptual issue in the literature. Although EDP is often discussed within STEM education, few studies specifically examine how it is practised in science education. Some studies interpret design primarily as physical construction (Chao et al., 2017), while others emphasise modelling (Valeeva et al., 2023), optimisation (Selcen Guzey et al., 2017), or general problem-solving tasks (Mohd Abeden & Siew, 2022). These differences are not merely methodological; they reflect different assumptions about what engineering integration should look like in science classrooms. As Schaben et al. (2022) suggest, the pedagogical and epistemic roles of EDP vary considerably across disciplines and contexts. This creates difficulty in comparing findings across studies, assessing the coherence of EDP implementation, and determining whether students are genuinely engaging in engineering design or simply completing hands-on science activities.

The ambiguity surrounding EDP integration also has implications for teachers and curriculum development. When the EDP is not clearly defined, teachers may struggle to distinguish between ordinary practical activities, inquiry-based learning, project-based learning, and engineering design activities. This lack of clarity may explain the hesitation many teachers experience when attempting to integrate engineering into science classrooms (Winarno et al., 2020). At the curriculum level, unclear conceptual boundaries may also affect how the EDP is aligned with science standards, 21st-century competencies, and integrated STEM learning goals. While studies such as Krajcik et al. (2014), Singer et al. (2016), and McFadden and Roehrig (2017) have highlighted the potential of EDP for curriculum design, teacher professional development, and standards-based science education, the field still lacks a clearer understanding of how the EDP is conceptualised and operationalised across research contexts. Previous bibliometric studies have also tended to focus on K–12 education in general (Ali & Tse, 2023; Sudrajat et al., 2022), which is typically organised by educational level. While this provides a useful overview, it does not clearly show how EDP is positioned within science education as a specific disciplinary field. Therefore, this study focuses on EDP in science education to better understand its research landscape, emerging trends, key contributors, and thematic development.

Previous Studies on Bibliometric Analysis

The bibliometric analysis employed performance analysis of research papers and interaction analysis between the researchers and their subject of study (Donthu et al., 2021). Bibliometric analysis of EDP has previously been conducted by Ali and Tse (2023) and Sudrajat et al. (2022), as shown in Table 1. According to Passas (2024), qualitative analysis of academic literature allows researchers to recognise the growth of EDP over time. This is crucial for advancing knowledge and targeting areas needing further investigation (Passas, 2024). Ali & Tse (2023), focused on EDP within formal K–12 science settings, highlighting its contribution to inquiry learning, design thinking, STEM competence, and gender-related patterns. Meanwhile, Sudrajat et al. (2022) offered a broader STEM-wide perspective, identifying thematic clusters around design thinking, problem-solving, classroom practices, and learning outcomes. Taken together, Sudrajat et al.'s (2022) bibliometric analysis offers a macro-level overview, while the work of Ali and Tse (2023) provides a more targeted exploration of EDP's role within formal school science settings. These analyses largely conclude their datasets around 2021 and share relatively similar bibliometric focuses.

Existing bibliometric studies have successfully mapped the growth, productivity, and thematic distribution of EDP research. However, the inclusion criteria implicitly treat the EDP as a stable and unified construct. Hence there is no synthesis of how design activity is defined, how engineering integration is epistemically framed, or how the EDP is operationalised across K–12 science disciplines. As a result, existing bibliometric work cannot explain the persistent conceptual ambiguity surrounding EDP implementation in science education.

Table 1
Previous studies on bibliometric analysis

Authors	Objectives	Data resource & year cover	Method	Total documents examined	Bibliometric attributes examined
Muhammad Ali, Alex Wing Cheung Tse	To identify the leading research trends, issues, and influential publications on the Engineering Design Process (EDP) for STEM education in K-12.	Web of Science (2011 to 2021)	Bibliometric Analysis	142	Research Trends (Keyword, Most Cited Publications and Authors, Most Cited Sources, Research Issues)
Ujang Sudrajat, Didit Ardianto, Irvan Permana	To map the evolution and trends of research on the Engineering Design Process in STEM education.	Google Scholar database ranging from 2016 to 2021 analyzed in this study	Bibliometric Analysis	762 out of 999	Metric, Author and year, Publisher, Name of Journal, Keyword representing each cluster

Therefore, unlike previous studies, this study incorporates the following features to advance the field; 1) the data set included articles from 2012 to 2025, 2) bibliometric mapping using a sense-making approach to conduct a systematic qualitative analysis; 3) examination of co-occurrence relationships among key concepts; 4) analysis of author productivity and co-authorship networks based on institutional and country affiliations at the time of publication; 5) the most cited sources and co-citation relationships between these sources. This study conducts a bibliometric analysis of EDP research in STEM education from 2012 to 2025, not only to map publication productivity and impact, but also to examine how design activity is conceptualised and how engineering and technology integration are operationalised across studies. The analysis focuses on how design activity and engineering and technology integration are signalled through bibliometric patterns, including keyword co-occurrence and thematic clustering. Accordingly, this study addresses the following research questions:

RQ 1: What is the current landscape of research on the Engineering Design Process in science education from 2012-2025?

RQ 2: What emerging trends are observable in the research of the Engineering Design Process within science education?

RQ 3: Which journals and publications have served as epicenters for ground-breaking studies on the Engineering Design Process in science education?

RQ 4: What landmark papers have shaped the discourse and trajectory of Engineering Design Process research in science education during this period?

RQ 5: Which key authors, institutions, and countries have prominently driven advancements in research on the Engineering Design Process in science education?

RQ 6: What pivotal research themes underpin the development and growth of the Engineering Design Process in the field of science education?

METHOD

This study's data sample was obtained by querying the Scopus core databases for publications from 2012 to 2025, resulting in a total of 915 documents that formed the initial dataset. This database was chosen over others like Google Scholar or Web of Science (WoS) to avoid duplicate records and inconsistencies arising from overlapping coverage and non-standardised indexing (Mongeon & Paul-Hus, 2016). Hence, this study employed data sourced from the Scopus database as of 4 August, 2025. The collected data encompassed a wide range of variables, such as document types, source types, languages, subject areas, publication trends, average authorship per document, institutional contributions, country-level publication distribution, and prominent keywords.

Search Strategy & Selection Procedure

The bibliometric review followed the modified PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic review reporting (Moher et al., 2009). The Scopus database was searched using two main groups of

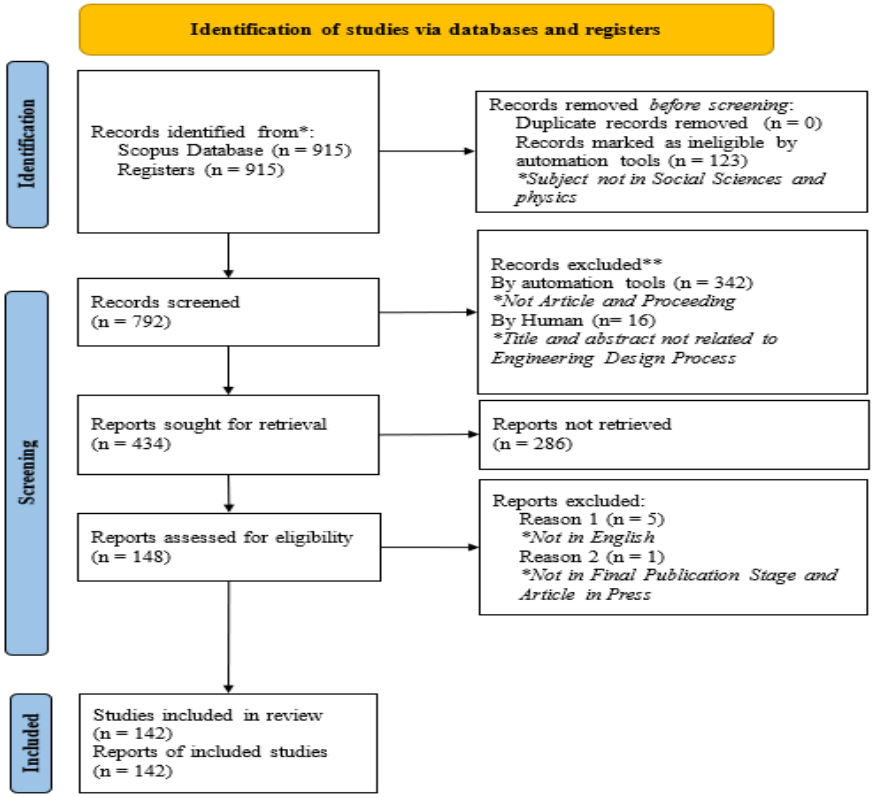
keywords: (1) engineering design and engineering integration terms ("engineering design process," "engineering design," "engineering practice*," "engineering integration," "engineering design-based learning," "design-based learning," "engineering design challenge*," and "EDP"), and (2) and science and STEM education-related terms ("science education," "science learning," "science teaching," "science instruction," "science classroom*," "STEM education," "STEM learning," "integrated STEM," and "STEM integration"). The following search string was used to search titles, abstracts, and keywords of all documents in the Scopus database:

TITLE-ABS-KEY ("engineering design process" OR "engineering design" OR "engineering practice*" OR "engineering integration" OR "engineering design-based learning" OR "design-based learning" OR "engineering design challenge*" OR EDP) AND TITLE-ABS-KEY ("science education" OR "science learning" OR "science teaching" OR "science instruction" OR "science classroom*" OR "STEM education" OR "STEM learning" OR "integrated STEM" OR "STEM integration")

The Scopus search, limited to records published between 2012 and 2025, initially yielded 915 documents. Before screening, 123 records were removed because they were not classified under relevant STEM-related subject areas (e.g., computer science or psychology), resulting in 792 records for screening. During the screening stage, 342 records were excluded using automated tools because they were not articles or conference papers. For quality assurance, only document types classified as articles, conference proceedings, and review papers were selected for this study because these document types represent primary and peer-reviewed scholarly outputs that are most suitable for citation, co-occurrence, and network analyses in bibliometric research (Donthu et al., 2021). After scanning abstracts, 16 papers were removed because their abstracts were not related to the engineering design process and science/STEM education. This left 434 reports for retrieval. Of these, 286 reports were not retrieved due to restricted access to the full-text articles, leaving 148 reports to be assessed for eligibility. A further 5 reports were excluded because they were not written in English, and another 1 report was not in the final publication stage. As a result, 142 studies were included in the final bibliometric dataset.

The final dataset focused specifically on the engineering design process in science education. The bibliographic metadata, including citation information, abstracts, author affiliations, source titles, and keywords, were exported from the Scopus in CSV format. The dataset was then cleaned and standardized to ensure consistency in author names, institutional affiliations, country names, keywords, and source titles before being analysed using bibliometric tools for performance analysis, science mapping, and co-occurrence analysis.

Figure 1
Flow diagram of the search strategy



Data Cleaning

Data cleaning and harmonisation are essential for ensuring accuracy and reliability of a bibliometric dataset. This study employed OpenRefine and biblioMagika® (Ahmi, 2023) in complementary ways to resolve discrepancies that frequently arise in large multidisciplinary datasets, particularly in author names, affiliations, heterogeneous keywords, and other bibliographic details. The clean dataset originated from CSV exports, which were then processed in stages. Specific columns such as keywords, authors' names, and affiliations were targeted for cleaning using clustering functions. Advanced bibliometric assessments were subsequently used with biblioMagika® for deeper structural checks, including the detection of missing metadata. Following data cleaning, the dataset was analysed using built-in bibliometric indicators grouped into four main categories: publication productivity, authorship and collaboration patterns, citation impact, and index-based research performance. These measures were used to examine trends across publication years, source titles, authors, institutions, and countries. Furthermore, biblioMagika® was used to identify missing data, enabling

manual completion of these gaps and facilitating the cleaning and harmonisation processes. This iterative process of verification, correction, and alignment ensured that the final dataset reflected a stable and interpretable body of literature. By prioritising semantic consistency and the integrity of bibliographic relationships, the cleaned dataset provided a dependable foundation for analysing how the EDP has evolved within science education.

Data Analysis

The data analysis was structured to directly address the research questions. The analysis involved mapping the current landscape of EDP research in science education, focusing on document types, source categories, languages, subject areas, and citation metrics. The findings were presented based on several criteria, such as annual publication volume, contributions from leading authors, prominent institutions, key countries, and influential source titles, highlighting major contributors and trends within the field. To assess the impact and significance of the publications, bibliometric indicators were used, including total publications, number of cited papers, total citations, citations per publication, citations per cited publication, h-index, g-index, m-index, and h-core citation count. Additionally, to uncover dominant themes and concepts in this field, methods such as co-occurrence network analysis, thematic mapping, and factorial analysis were applied to visualise the authors' keywords. These visualisations allowed for the identification of topic clusters, detection of patterns, and exploration of connections among various research subfields.

Tools

The study utilized a range of tools to construct a coherent and reliable dataset for analysis through two staged data processing workflows. The initial screening and structuring of raw records were conducted manually using Microsoft Excel. This allowed careful verification of duplicated entries, incomplete metadata and inconsistencies in publication details, enabling their removal. Following this, biblioMagika® was employed to reconcile variations in institutional names, countries, labels, and authors affiliations. These were the key steps during the second stage, given the diverse international contribution to EDP research. OpenRefine was applied for deeper semantic cleaning of author keywords. This helped consolidate synonyms, spelling variants and fragmented conceptual labels. After establishing a stable dataset, VOSviewer generated informative visual representations of the research findings, with Mendeley serving as the reference manager. Taken together, this multi-layered approach supported a thorough and rigorous examination of the research landscape surrounding the EDP in science education.

FINDINGS

The following results section presents an in-depth analysis of the research landscape on engineering design process in science/STEM education, addressing the research questions and providing insights relevant to scholars, practitioners, and decision-makers.

RQ 1: What is the current landscape of research on the Engineering Design Process in science education from 2012-2025?

To address the primary research objective of mapping the current landscape of studies on the EDP, the bibliometric parameters were analysed based on document type, source category, language, and subject area. Citation metrics were also assessed to evaluate the scholarly impact and visibility of contributions in this field (Donthu et al., 2021). All journal articles, conference proceedings, and review papers were included because they undergo a peer-reviewed process. Covering the period from 2012 to 2025, the dataset comprised 142 publications involving 536 contributing authors, reflecting a strong pattern of academic collaboration.

Table 2
Citation metric

Main Information	Data
Publication Years	2012 - 2025
Total Publications	142
Citable Year	14
Number of Contributing Authors (NCA)	536
Number of Cited Papers	120
Total Citations	2,208
Citation per Paper	15.55
Citation per Cited Paper	18.40
Citation per Year	169.85
Citation per Author	4.12
Author per Paper	3.77
Citation sum within h-Core	2,020
h-index	27
g-index	43
m-index	1.929

The analysis recorded a total of 2,208 citations, resulting in an average of 15.55 citations per publication. Notably, the average citation rate for cited documents increased to 18.40, demonstrating concentrated academic interest in high-impact contributions. Additional indicators further support this finding: the dataset achieved a citation rate of 169.85 citations per year, with an average of 4.12 citations per author. The total citation sum within the h-core was 2,020, highlighting the lasting relevance of the most influential works. The bibliometric indices are h-index (27), g-index (43), and m-index (1.929), which underscore the maturity and scholarly productivity of the research field over 14 citable years. Furthermore, an average of 3.77 authors per publication points to the interdisciplinary and collaborative nature of EDP research. Collectively, these metrics illustrate not only the volume and consistency of research output but also the intellectual depth and growing academic influence of the EDP within science education.

RQ 2: What emerging trends are observable in the research of the Engineering Design Process within science education?

A steady growth in publication output is observed over the years, with a notable

increase beginning in 2020. The year 2022 recorded the highest number of publications, with 25 documents contributing to a peak of 487 total citations. This upward trend, punctuated by periodic surges in 2015, 2016, 2020, and 2022, reflects growing scholarly engagement and the rising influence of EDP within the educational research landscape. Figure 2 and Table 2 further illustrate this development, with the citation line graph reflecting the overall rise in academic interest and research output. Parallel to the growth in publication count, there was a marked increase in the Number of Contributing Authors (NCA), which rose from 3 authors in 2012 to a peak of 99 in 2022. This growth signals the expanding collaborative network of researchers working within the EDP domain. The consistent rise in author contributions highlights both the growing academic recognition of EDP and its positioning as a significant research theme in contemporary science education.

From the perspective of scholarly impact, the h-index reached 27 and the g-index peaked at 43 across the examined period, with annual h-index values rising notably in 2020 and 2022. These metrics point to the growing citation strength and recognition of influential publications in the field. The m-index, which accounts for scholarly impact adjusted for time, peaked at 2.2 in 2020, indicating a concentration of impactful publications during that period. This pattern suggests a maturing field with sustained scholarly output and influence. Although citation rates fluctuated and declined slightly after 2022, such variability is not uncommon in emerging fields and may be attributed to citation latency or shifts in research focus. Further investigation into citation behaviour and document quality is recommended to contextualize these fluctuations. Overall, these metrics collectively affirm the increasing importance of EDP research in science education, underscoring its evolution into a core component of STEM pedagogical inquiry and innovation.

Figure 2
Total publications and citations by year (Excluding the year 2024 as data is only available up to 19 October 2024)

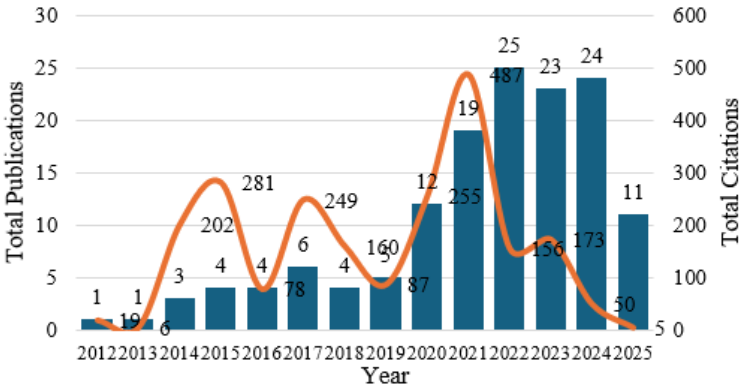


Table 3
Publication by year

Year	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
2012	1	3	1	19	19.00	19.00	1	1	0.071
2013	1	1	1	6	6.00	6.00	1	1	0.077
2014	3	15	3	202	67.33	67.33	3	3	0.250
2015	4	14	4	281	70.25	70.25	4	4	0.364
2016	4	17	4	78	19.50	19.50	4	4	0.400
2017	6	16	6	249	41.50	41.50	5	6	0.556
2018	4	14	4	160	40.00	40.00	4	4	0.500
2019	5	15	5	87	17.40	17.40	4	5	0.571
2020	12	44	12	255	21.25	21.25	7	12	1.167
2021	19	83	19	487	25.63	25.63	11	19	2.200
2022	25	96	23	156	6.24	6.78	7	10	1.750
2023	23	78	21	173	7.52	8.24	8	12	2.667
2024	24	110	14	50	2.08	3.57	4	5	2.000
2025	11	30	3	5	0.45	1.67	1	2	1.000
Grand Total	142	536	120	2208	15.55	18.40	27	43	1.929

Notes: TP = total number of publications; NCA = number of contributing authors; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index.
* Publication data for the year 2025 is only up until 31 July 2025

RQ 3: Which journals and publications have served as epicentres for ground-breaking studies on the EDP in science education?

Table 4 presents the most active source titles contributing to research on the EDP in science education, focusing on journals that published two or more documents. Education Sciences emerged as the most prolific outlet, with a total of 10 publications and 36 citations, demonstrating consistent engagement with EDP-related scholarship despite a relatively modest citation rate (C/P = 3.60). Frontiers in Education follows closely with nine publications and 55 total citations, reflecting its growing role as a platform for interdisciplinary STEM and engineering education research. Both the Eurasia Journal of Mathematics, Science and Technology Education and the International Journal of STEM Education recorded eight publications each. Notably, the International Journal of STEM Education stands out for its exceptionally high impact, accumulating 500 citations and achieving the highest average citations per publication (C/P = 62.50), indicating its central influence in shaping high-impact EDP research.

The International Journal of Technology and Design Education also demonstrates a strong and sustained contribution, with five publications and 71 citations, highlighting its focus on design-based pedagogical innovations. Among journals with four publications, the Journal of Research in Science Teaching and the Journal of Science Teacher Education exhibit particularly high citation impact, with 167 and 289 total citations respectively, underscoring their prominence in advancing theoretical and empirical discussions on engineering and science education. Sustainability (Switzerland) similarly shows substantial influence, with four publications and 127 citations, reflecting increasing interest in EDP within sustainability-oriented educational research. Other contributing journals, including Science Education and American Biology Teacher, provide additional disciplinary breadth, reinforcing the

interdisciplinary nature of EDP research. Collectively, these publication patterns highlight the field's maturity, its strong grounding in leading science education journals, and the expanding recognition of engineering design as a critical framework for inquiry-driven and problem-solving-oriented science learning.

Table 4
Most active source titles publishing two or more documents

Source Title	TP	NCA	NCP	TC	C/P	C/CP	h	g	M
Education Sciences	10	10	7	36	3.60	5.14	4	5	0.800
Frontiers in Education	9	9	6	55	6.11	9.17	3	7	0.750
Eurasia Journal of Mathematics, Science and Technology Education	8	8	7	71	8.88	10.14	4	8	0.500
International Journal of STEM Education	8	8	8	500	62.50	62.50	8	8	0.727
International Journal of Technology and Design Education	5	5	5	71	14.20	14.20	4	5	0.571
Journal of Research in Science Teaching	4	4	4	167	41.75	41.75	4	4	0.444
Sustainability (Switzerland)	4	4	3	127	31.75	42.33	3	4	0.500
Journal of Science Teacher Education	4	4	4	289	72.25	72.25	3	4	0.250
Science Education	3	3	2	112	37.33	56.00	2	3	0.200
American Biology Teacher	3	3	1	5	1.67	5.00	1	2	0.100

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h = h-index; g = g-index; m = m-index

RQ4: What landmark papers have shaped the discourse and trajectory of Engineering Design Process research in science education during this period?

Table 5 presents the five most highly cited publications that have significantly shaped the discourse on the EDP in science education. Leading the list is the article by Krajcik et al. (2014), *Planning Instruction to Meet the Intent of the Next Generation Science Standards*, with 163 total citations and an annual citation rate of 13.58. This work underscores the pivotal role of curriculum alignment and instructional planning in promoting design-based science learning, setting a foundation for subsequent research in this domain. Closely following is the study by English and King (2015), which explores STEM learning through engineering design in aerospace contexts among fourth-grade students. Garnering 159 citations and achieving the highest citation per year (14.45) in the list, it highlights the effectiveness of hands-on design tasks in enhancing scientific understanding. Reiser et al. (2021) contribute with 111 citations and the highest annual citation average (22.20), emphasizing the coherence of storyline units in supporting student perspectives in EDP-based science instruction. Meanwhile, Brown (2017) provides a critical metasynthesis on inquiry-based and culturally responsive science education, cited 99 times, reinforcing the importance of equity and inclusion in design-focused pedagogies. Purzer et al. (2015) round out the list with a study on engineering design behaviors associated with scientific explanations, cited 85 times with a C/Y of 7.73, offering insights into how informed design processes intersect with core scientific reasoning. Collectively, these influential publications reflect the increasing academic interest in integrating engineering design into science education, marking EDP as a transformative approach to fostering engagement, critical thinking, and contextual problem-solving among learners.

Table 5
Top five (5) highly cited articles

No.	Author(s)	Title	Journal	TC	C/Y
1.	Krajcik J.; Codere S.; Dahsah C.; Bayer R.; Mun K. (2014)	Planning Instruction to Meet the Intent of the Next Generation Science Standards	Journal of Science Teacher Education	163	13.58
2.	English L.D.; King D.T. (2015)	STEM learning through engineering design: fourth-grade students' investigations in aerospace	International Journal of STEM Education	159	14.45
3.	Reiser B.J.; Novak M.; McGill T.A.W.; Penuel W.R. (2021)	Storyline Units: An Instructional Model to Support Coherence from the Students' Perspective	Journal of Science Teacher Education	111	22.20
4.	Brown J.C. (2017)	A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning	Journal of Research in Science Teaching	99	11.00
5.	Purzer Ş.; Goldstein M.H.; Adams R.S.; Xie C.; Nourian S. (2015)	An exploratory study of informed engineering design behaviors associated with scientific explanations	International Journal of STEM Education	85	7.73

RQ 5: Which key authors, institutions, and countries have prominently driven advancements in research on the Engineering Design Process in science education?

Table 6 represents the most prolific authors in the field of Engineering Design Process (EDP) in science education.

Table 6 highlights the most prolific authors in the field of Engineering Design Process (EDP) in science education, focusing on individuals with the highest publication counts. Leading this group is Leonora Kaldaras of the University of Colorado Boulder, United States, with a total of two publications. Following Kaldaras is Kimberly B. Christian from Stony Brook University, United States, who recorded a single publication that received 61 citations, averaging 61.00 citations per publication. Similarly, Şenay Purzer from Purdue University, United States, has a single publication with 85 citations, indicating exceptional influence.

Other notable contributors include Markus Reiser from Weingarten University of Education, Germany, and Luecha Ladachart from the University of Phayao, Thailand. Markus Reiser has published three documents, while Luecha Ladachart has published two. Both have received moderate citation counts ranging from 6 to 14, with h-index values of 1 to 2 and m-indices between 0.250 and 0.500. Sufirman Arifin from Universiti Malaysia Sabah represents a contributor from the Malaysian research landscape, with two publications and three total citations, reinforcing the international and multicultural reach of the research community engaging with EDP in science education. Collectively, these authors represent a growing global network of researchers, with varying degrees of scholarly output and influence. Their contributions highlight the interdisciplinary and international nature of EDP-related scholarship and reflect the expanding scope and relevance of engineering design within science education frameworks.

Table 6
Most productive authors who published two to three documents

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Reiser, Markus	Weingarten University of Education	Germany	3	1	6	2.00	6.00	1	2	0.500
Ladachart, Luecha	University of Phayao	Thailand	2	2	7	3.50	3.50	2	2	0.500
Bopardikar, Anushree	University of Twente	United States	2	2	13	6.50	6.50	2	2	0.333
Kaldaras, Leonora	University of Colorado Boulder	United States	2	2	54	27.00	27.00	2	2	0.400
Arifin, Sufirman	Universiti Malaysia Sabah	Malaysia	2	1	3	1.50	3.00	1	1	0.333

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index

Table 7 presents the most productive institutions contributing to the field of Engineering Design Process (EDP) in science education, focusing on those with a minimum of two publications. Leading this group is Purdue University in the United States, which recorded five publications with a total of 234 citations. Following is Michigan State University with four publications and a total of 223 citations, achieving an average of 55.75 citations per publication. The University of California has also contributed significantly, with three publications resulting in 20 citations and an average of 6.67 citations per paper.

From the University of Twente onwards, the pattern becomes more internationally distributed. The University of Twente in the Netherlands and the University of Phayao in Thailand represent important contributors outside the United States. Weingarten University of Education in Germany, The Hague University of Applied Sciences in the Netherlands, Utrecht University in the Netherlands, and the University of Helsinki in Finland further demonstrate the wider institutional spread of this field. Contributions from the University of Dubuque and the University of Minnesota in the United States, Hanoi National University of Education in Vietnam, Van Yuzuncu Yil University in Turkey, Universiti Malaysia Sabah in Malaysia, Queensland University of Technology in Australia, and Linköping University in Sweden further show that EDP research in science education has attracted attention across diverse regional and academic contexts. Although most of these institutions contributed only a small number of publications, several achieved comparatively strong citation impact.

Table 7
Most productive institutions with at least two publications

Institution Name	Country	TP	NCP	TC	C/P	C/CP	h	g	m
Purdue University	United States	5	4	234	46.80	58.50	4	5	0.364
Michigan State University	United States	4	4	223	55.75	55.75	4	4	0.333
University of California	United States	3	2	20	6.67	10.00	2	3	0.154
University of Twente	Netherlands	3	3	67	22.33	22.33	3	3	0.500
University of Phayao	Thailand	3	3	36	12.00	12.00	2	3	0.500
University of Education Weingarten	Germany	3	1	6	2.00	6.00	1	2	0.500
The Hague University of Applied Sciences	Netherlands	2	2	19	9.50	9.50	2	2	0.500
Utrecht University	Netherlands	2	2	30	15.00	15.00	1	2	0.100
University of Dubuque	United States	2	2	3	1.50	1.50	1	1	0.333
Ha Noi National University of Education	Viet Nam	2	2	6	3.00	3.00	2	2	0.333
Van Yuzuncu Yil University	Turkey	2	1	5	2.50	5.00	1	2	0.250
Universiti Malaysia Sabah	Malaysia	2	1	4	2.00	4.00	1	2	0.500
University of Helsinki	Finland	2	2	45	22.50	22.50	2	2	0.250
Queensland University of Technology	Australia	2	2	178	89.00	89.00	2	2	0.143
Linköping University	Sweden	2	2	19	9.50	9.50	1	2	0.333
University of Minnesota	United States	2	2	141	70.50	70.50	2	2	0.222

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index

Figure 3 and Table 7 illustrate the global research contributions in the field of Engineering Design Process (EDP) in science education. Overall, the pattern shows that the field is strongly led by the United States, which demonstrates both the highest publication ouput and the strongest citation impact. Beyond this leading position, Indonesia recorded 19 publications and 68 citations, showing strong productivity but relatively lower citation impact. The United Kingdom contributed 10 publications with 201 citations, while Australia produced nine publications with 274 citations, suggesting that both countries have strong citation influence despite a smaller publication volume. Turkey and China each recorded nine publications, but their citation patterns differ, with Turkey receiving 40 citations and China receiving 24 citations. The Netherlands, Malaysia, Thailand, and Spain contributed fewer publications, ranging from five to seven, yet some of these countries show meaningful citation visibility, particularly Spain with 85 citations and the Netherlands with 66 citations.

Figure 3
Visualisation of global distribution of engineering design process in science education research

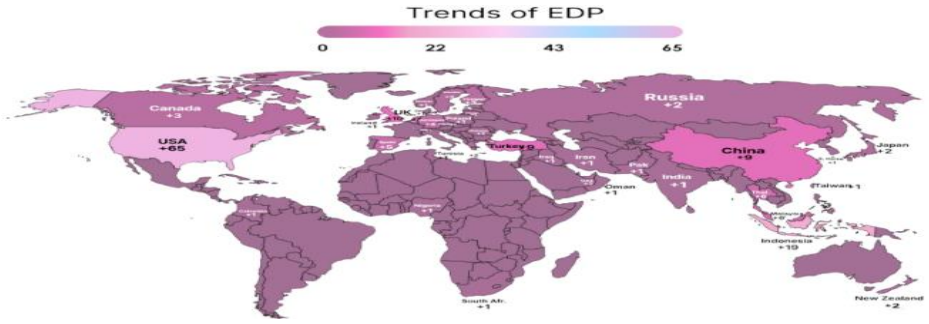


Table 7
Countries contributing nine or more publications

Country	TP	NCP	TC	C/P	C/CP	h	g	m
United States	65	24	52	1357	20.88	26.10	19	36
Indonesia	19	51	12	68	3.58	5.67	6	8
United Kingdom	10	9	9	201	20.10	22.33	7	10
Turkey	9	7	7	40	4.44	5.71	4	6
Australia	9	10	9	274	30.44	30.44	6	9
China	9	11	8	24	2.67	3.00	3	4
Netherlands	7	NR	6	66	9.43	11.00	3	7
Malaysia	6	11	4	37	6.17	9.25	3	6
Thailand	6	NR	5	44	7.33	8.80	3	6
Spain	5	2	5	85	17.00	17.00	4	5
United States	65	24	52	1357	20.88	26.10	19	36

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; g = g-index; m = m-index

RQ 6: What pivotal research themes underpin the development and growth of the Engineering Design Process in the field of science education?

The co-occurrence network shown in Figure 4 provides an in-depth visualization of major research themes and their interrelationships within the field of EDP in science education. The map, generated using VOSviewer and based on keywords appearing a minimum of 10 times, reveals a network of interconnected thematic clusters. At the center of the network, the terms “engineering design process” and “science education” emerge as dominant nodes, indicating their foundational role in this research area. Their proximity suggests a strong link between engineering-based design practices and science education outcomes. Surrounding these core elements are several peripheral yet thematically distinct clusters that represent key research focuses. One of the most prominent clusters is centered around “STEM education” and “design thinking.” This cluster integrates research efforts on fostering critical thinking and interdisciplinary problem-solving through structured engineering tasks. It reflects the pedagogical shift from rote instruction to inquiry-based and project-based learning approaches, where students actively participate in the design and iteration of scientific solutions. Closely

linked to this are the themes of "module development" and "science technologies," emphasizing the role of curriculum design and technological tools in supporting EDP implementation in classroom contexts.

Figure 4
Co-occurrence network of authors' keywords with at least 10 occurrences

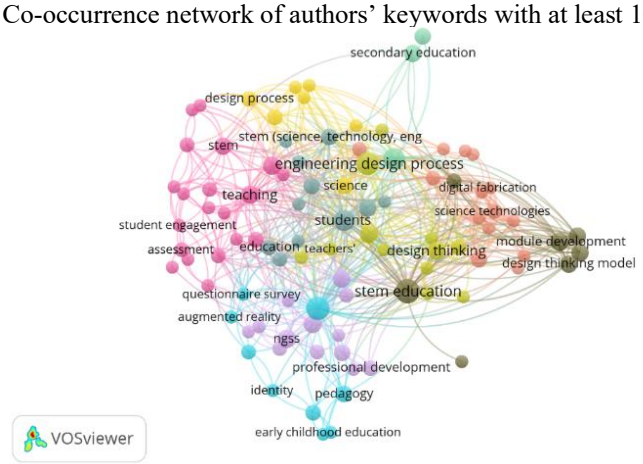


Table 8
Top 5 co-occurrence network of the author's keywords

Research Topics	Occurrences	Total link strength
STEM education	10	37
Secondary education	8	36
Science education	6	11
Module development	5	30
Engineering Design Process	4	4

These clusters demonstrate the breadth of research in this field and signal a growing interdisciplinary interest across STEM domains. Overall, the network of co-occurring keywords reflects both the diversity and the maturity of scholarship on the Engineering Design Process in science education. The map reveals dominant research themes and serves as a valuable reference for identifying emerging topics. It also guides future research and supports the strategic development of curricula that integrate engineering practices into science classroom contexts.

DISCUSSION

This study synthesises 142 publications on the Engineering Design Process (EDP) in science education published between 2012 and 2025. The findings reveal a gradual increase in publication output across the review period, with research activity reaching its highest point in 2022, when 25 publications and 156 citations were recorded. This pattern suggests that EDP has gained increasing scholarly attention as science education research continues to emphasise STEM integration, design-based learning, and real-world problem-solving. The field's cumulative citation count of 2,208, together with an

h-index of 27 and a g-index of 43, further reflects its substantial scholarly impact and growing influence within science education research.

Previous bibliometric studies have primarily explored EDP from a broader STEM perspective. For example, Ali and Tse (2023) analysed 142 publications related to EDP in K–12 STEM education and identified major research themes including professional development, design thinking, STEM competencies, scientific inquiry, and gender disparities. Similarly, Sudrajat et al. (2022) mapped 762 publications on EDP and highlighted dominant themes associated with STEM implementation, engineering practices, and design thinking. While these studies successfully documented publication trends and thematic distributions, they treated EDP largely as a general STEM construct. In contrast, the present study demonstrates that EDP research has increasingly shifted towards science education contexts, where engineering practices are integrated as mechanisms to support scientific inquiry, problem-solving, and conceptual learning. This shift reflects broader curriculum reforms influenced by frameworks such as the Next Generation Science Standards (NGSS), which emphasise the integration of science and engineering practices.

Recent studies in the dataset, particularly those published since 2020, foreground engineering design as a mechanism for supporting modelling, iteration, justification of solutions, and evaluation of outcomes. Influential works such as Krajcik et al. (2014), English and King (2015), and Reiser et al. (2021) exemplify this shift by situating EDP within coherent curricular structures that integrate scientific inquiry with engineering reasoning. Moreover, Abdurrahman et al. (2023) show the impact of EDP on students' thinking skills in science learning. Similarly, Yu et al. (2020) highlight a positive impact towards students' critical thinking when EDP is integrated into their learning process. However, despite all the positive impact on EDP in science education, several research gaps persist. These limitations suggest that current findings may not fully explain how knowledge is developed through the knowledge transfer process when EDP emerges in science education. Future research should therefore move beyond isolated classroom studies by involving diverse participants, multiple data sources, and varied teaching contexts. This would help establish whether the findings are consistent across settings and identify the conditions that support effective implementation.

CONCLUSION

In conclusion, this bibliometric analysis provides a comprehensive overview of the research landscape surrounding the Engineering Design Process (EDP) in science education. The findings reveal a gradual growth in scholarly output from 2012 to 2025, reflecting the growing recognition of EDP as one of the pedagogical approaches that foster critical thinking, creativity, and problem-solving within STEM education. Rather than suggesting that EDP universally transforms science education, the findings show that the field is still developing and requires further empirical and conceptual clarification. Ultimately, the findings serve to guide educators, researchers, and policymakers in advancing equitable and impactful science education through the structured integration of engineering design. Future research should therefore examine how EDP is implemented across different science subjects, school levels, and classroom

contexts. More studies are also needed on teacher professional development, curriculum alignment with science and engineering practices, and the role of emerging technologies such as augmented reality in supporting EDP-based learning.

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