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Experiential Learning in Engineering Education: A Bibliometric Analysis of Perceptions and Transformations

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Abstract

Experiential learning has emerged as a central approach in engineering education, fostering student engagement, problem-solving, and professional skill development. To map this evolving field, a bibliometric analysis was conducted using data retrieved from Scopus on 1 September 2025, covering 694 publications from 2010 to 2024. Analyses with VOSviewer examined publication trends, keyword co-occurrence, and collaboration patterns. Results show steady growth, with a sharp increase after 2020, driven by digital transformation and the COVID-19 pandemic. Four thematic clusters were identified: (1) project- and problem-based learning, (2) student engagement and perceptions, (3) technology-enhanced learning, and (4) professional development and sustainability. The United States dominates output and citations, while Denmark and Portugal lead through influential scholars and institutions such as Aalborg University and the University of Minho. Collaboration remains fragmented, with limited cross-regional links. The study highlights strengths, gaps, and opportunities, offering guidance for educators, policymakers, and researchers to advance experiential learning in engineering education.

***Keywords*— Experiential Learning, bibliometric analysis, Engineering Education.**

I. INTRODUCTION

In the evolving landscape of engineering education, traditional lecture-based methods are increasingly being complemented—or even supplanted—by experiential learning strategies [1]. Engineering, by its nature, is an applied discipline, and students often benefit from pedagogical approaches that align with hands-on, real-world experiences [2]. The integration of experiential learning—defined broadly as the process of learning through direct experience, reflection, and application—has become a crucial focus for educators aiming to bridge the gap between theoretical knowledge and professional practice [3]. The pedagogical foundation for experiential learning in engineering is rooted in the experiential learning theory (ELT) developed by David Kolb [4]. According to Kolb, effective learning occurs when students move through a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation. This theory has informed the design of project-based learning (PBL), cooperative education, internships, simulations, and other student-centered teaching methods across engineering curricula worldwide [5].

Over the past two decades, there has been growing interest in investigating the effectiveness, student perceptions, and transformative potential of experiential learning within engineering contexts [6].

This interest has been fueled in part by demands from industry stakeholders who expect graduates to demonstrate not just academic proficiency but also soft skills such as teamwork, problem-solving, adaptability, and communication [7]. Moreover, the emergence of Education 4.0—driven by Industry 4.0 technologies—has further accelerated the need for adaptive, interdisciplinary, and personalized learning experiences that simulate the complexity of real engineering environments [8].

Engineering education is undergoing a profound transformation due to technological, economic, and societal changes [9]. These changes require engineers who are not only technically proficient but also socially aware, globally competent, and capable of lifelong learning [10]. Experiential learning plays a crucial role in addressing these demands by engaging students in active, authentic learning processes [6].

As emphasized by Tembrevilla and Phillion (2024), experiential learning in engineering programs enables students to understand abstract concepts by applying them in real contexts, thereby improving retention and cognitive depth [6]. Furthermore, such pedagogies encourage reflective practices and help students develop metacognitive awareness—key to innovation and leadership in engineering fields [11].

The rise of student design competitions, living labs, and industry-university partnerships has provided unique platforms for experiential learning [12]. These initiatives have allowed learners to work in multidisciplinary teams, tackle open-ended problems, and engage with external stakeholders [13]. However, the breadth of strategies labeled as "experiential" and the diverse educational outcomes they aim to achieve have led to calls for more systematic, evidence-based analysis of their implementation and impact [6].

Despite the widespread adoption of experiential learning in engineering education, there remains a lack of consolidated knowledge regarding its scope, theoretical evolution, effectiveness, and research trends [9]. A bibliometric analysis serves as an essential tool to map out the intellectual structure of the field. It helps identify key research themes, leading scholars, influential publications, and collaboration networks [14].

Bibliometric studies also reveal the evolution of discourse and highlight shifts in emphasis—from initial studies focused on curriculum innovation to recent work on digital transformation, sustainability, and artificial intelligence in experiential settings [9, 10].

This study seeks to fill this gap by offering a comprehensive bibliometric analysis of experiential learning in engineering education, focusing on how it has been perceived, applied, and transformed over time. In doing so, it contributes to ongoing efforts to enhance evidence-based teaching practices and align engineering programs with global workforce needs.

II. METHODOLOGY

The methodological workflow is illustrated in Figure1, comprising two main phases: literature search and data screening.

The bibliometric dataset was retrieved from the Scopus database on 1 September 2025, as Scopus offers broad coverage of engineering and education-related publications. A comprehensive search strategy was employed using Boolean operators to combine experiential learning terms ("experiential learning" OR "hands-on learning" OR "practical learning" OR "project-based learning" OR "work-integrated learning" OR "active learning") AND (“engineering education" OR "engineering teaching" OR "engineering pedagogy"). To capture studies focusing on perceptions and transformations, additional keywords were included (perception OR attitude OR transformation OR reform OR effectiveness OR outcomes). This initial search yielded a total of 3,497 documents.

A systematic screening procedure was then applied to refine the dataset (Figure 1). First, a time filter restricted the period to 2010–2024, as research on experiential learning in engineering gained significant momentum during this timeframe. Second, the dataset was limited to peer-reviewed journal articles to ensure scholarly quality and rigor. Third, only documents published in the English language were retained to ensure consistency in analysis. Finally, documents unrelated to the context of experiential learning in engineering education were excluded after a manual relevance check. Following this screening process, the final dataset comprised 694 documents, which served as the basis for descriptive statistics, keyword co-occurrence analysis, and collaboration network mapping.

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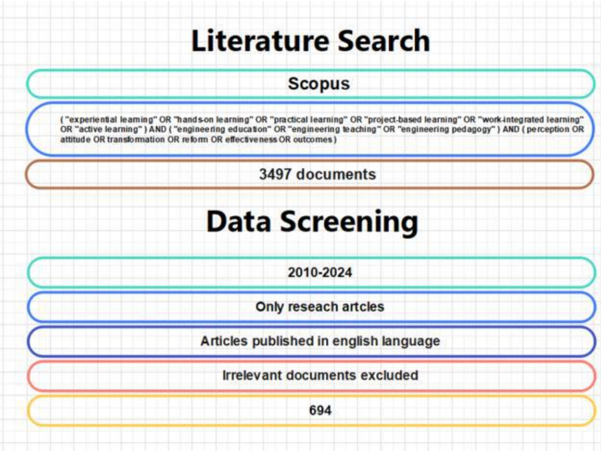

Fig. 1: Literature search

III. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

As shown in Figure 2, research output on experiential learning in engineering education has experienced steady and accelerating growth over the past 15 years. The earliest years of the analysis (2010–2013) reflect a nascent stage, with fewer than 25 publications per year, indicating limited but emerging interest in integrating experiential approaches such as project-based learning and problem-based learning into engineering curricula. A gradual increase is observed from 2014 to 2017, when annual publications consistently surpassed 40 papers, reflecting a growing recognition of active learning methods within engineering education research.

The period from 2018 onward marks a rapid expansion phase, with annual publications rising above 60 and continuing to grow each year. Notably, the number of publications surged significantly after 2020, coinciding with the global COVID-19 pandemic, which accelerated the adoption of blended and online experiential learning practices. By 2024, annual publications reached 114 papers, representing the highest output within the study period.

The cumulative trend line highlights the exponential nature of growth, with the total number of publications increasing from fewer than 100 in 2013 to nearly 700 documents by 2024. This trajectory suggests that experiential learning has transitioned from a marginal pedagogical innovation to a mainstream research focus in engineering education. The sharp upward trend after 2020 also indicates a sustained scholarly commitment to exploring not only traditional models such as project- and problem-based learning but also technology-enhanced approaches including virtual reality, augmented reality, and artificial intelligence.

Overall, the publication trend demonstrates that experiential learning has become a critical and fast-growing research domain within engineering education, reflecting its importance in addressing the evolving demands of industry, sustainability, and digital transformation.

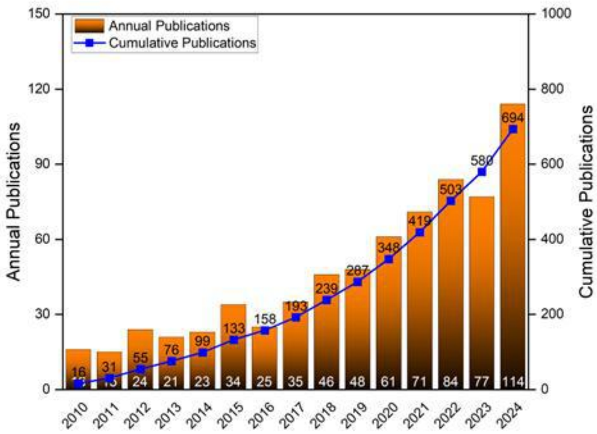

Fig. 2: Publication Tread

The analysis of publication sources reveals that experiential learning in engineering education is a truly multidisciplinary field, with contributions spread across 197 different journals. This breadth reflects the diversity of perspectives — spanning engineering education, pedagogy, technology-enhanced learning, and sustainability. However, a relatively small set of journals contributes disproportionately to the knowledge base, as highlighted in Table 1.

Table 1: Top ten sources

Rank	Journal	TP	TC	CPP	H	YA
1	International Journal of Engineering Education	96	1060	11.04	17	2010-24
2	IEEE Transactions on Education	69	1331	19.29	22	2010-24
3	Journal of Engineering Education Transformations	59	171	2.90	6	2018-24
4	European Journal of Engineering Education	54	2080	38.52	26	2011-24
5	Computer Applications in Engineering Education	23	232	10.09	9	2015-24
6	Advances in Engineering Education	17	290	17.06	8	2010-24
7	Sustainability	17	246	14.47	9	2020-24
8	Education for Chemical Engineers	16	377	23.56	10	2016-24
9	Journal of Engineering Education	16	674	42.13	14	2010-24
10	Education Sciences	14	249	17.79	8	2019-24

The International Journal of Engineering Education (IJEE) leads with 96 publications between 2010 and 2024, confirming its role as a flagship outlet for pedagogical innovation in engineering. The IEEE Transactions on Education ranks second with 69 publications, but it surpasses IJEE in total citations (1,331) and citations per paper (CPP = 19.29), underscoring its high impact within the engineering education research community.

Overall, while research is distributed across nearly 200 journals, these top 10 sources account for a significant share of output and citations, serving as the primary channels for scholarly discourse. This concentration underscores that although the field is diverse, it also maintains a set of core journals where experiential learning research achieves visibility and impact.

3.2 Keyword Co-occurrence Clusters

The keyword co-occurrence network in Figure 3 illustrates the intellectual structure of experiential learning in engineering education. From the total of 4,298 unique keywords, only those appearing 15 times or more were included in the visualization, ensuring that the map reflects the most prominent and influential research themes. The resulting clusters highlight the thematic diversity and interconnections within the field.

The largest node, "engineering education", appears at the center of the network, signifying its role as the dominant anchor term. Surrounding this core, several thematic clusters can be identified:

Cluster 1 – Project- and Problem-based Learning (Red cluster)

Keywords: project-based learning, problem-based learning, curriculum, educational computing, software engineering.

This cluster emphasizes structured pedagogical models that encourage hands-on, inquiry-driven learning, strongly linked to curriculum reform and computing/engineering design contexts.

Cluster 2 – Active Learning and Student Engagement (Blue cluster)

Keywords: active learning, flipped classroom, student learning, student engagement, student perceptions, motivation.

This theme centers on approaches that enhance classroom interaction and learner-centered practices, reflecting growing attention to student experience and perception studies.

Cluster 3 – Experiential and Applied Contexts (Green cluster)

Keywords: experiential learning, higher education, sustainable development, innovation, teamwork, laboratories, design.

This cluster highlights the application of experiential approaches in broader contexts, including sustainability and innovation, aligning engineering education with global challenges.

Cluster 4 – Technology-Enhanced Learning (Yellow cluster)

Keywords: e-learning, online learning, virtual reality, augmented reality, computer-aided instruction, learning environments.

The prominence of these terms reflects the digital transformation of experiential learning, accelerated by the COVID-19 pandemic, and the rise of virtual platforms for immersive and remote education.

The strong interconnections among clusters demonstrate that research in experiential learning is highly interdisciplinary and overlapping, rather than siloed. For example, project-based learning links closely to active learning and student engagement, while sustainability connects both to curriculum innovation and technology-enhanced environments.

The frequency threshold of 15 ensures that only the most consistent themes are highlighted, filtering out sporadic or niche topics. This approach reveals that experiential learning research has matured into four dominant and interconnected research streams: pedagogical frameworks, learner engagement, applied/sustainable contexts, and digital/technology integration.

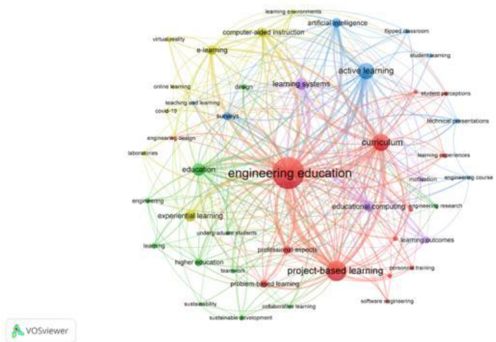

Fig. 3: keywords occurrences

3.3: Prominent Authors, Institutions, and Countries

Out of 2,127 contributing authors (Table 2), only a small group show consistent productivity and high impact. Kolmos, Anette Jensen (Aalborg University, Denmark) leads with 9 publications and the highest influence (652 citations, CPP = 72.44), reflecting her pioneering role in problem- and project-based learning (PBL). Lima, Rui M. (University of Minho, Portugal) and Mesquita, Diana (Catholic University of Portugal) both contribute 8 publications, with CPP

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values of 39.75 and 34.13, respectively, focusing on curriculum and project-based learning. Du, Xiangyun (Aalborg University) and Fernandes, Sandra Raquel Gonçalves (Instituto Politécnico do Porto, Portugal) also rank highly, each with strong citation impacts (CPP > 50). Bhajan et al, (Figure 4) greatly enhancing the learning by doing experience of physical students related to chemical kinetics and phase behaviour through field trips, case studies, adjunct lecture as well as gas hydrate lab visit in Chemical Engineering Department at Universiti Teknologi PETRONAS Malaysia.

Fig. 4: Gas Hydrate lab visits by Physical Chemistry students (Universiti Teknologi PETRONAS)

Overall, the leading scholars are concentrated in Denmark and Portugal, highlighting these regions as hubs of experiential learning research in engineering education. Despite broad participation, intellectual leadership is anchored by this relatively small group of highly cited authors.

Table: 2 Top 5 authors

Rank	author	Institution/Country	TP	TC	CPP	H	YA
1	kolmos, anette jepsen	Aalborg University, Denmark	9	652	72.44	6	2011-23
2	lima, rui m.	University of Minho, Portugal	8	318	39.75	6	2012-24
3	mesquita, diana	Catholic University of Portugal, Portugal	8	273	34.13	6	2011-24
4	du, xiangyun	Aalborg University, Denmark	7	387	55.29	6	2021-23
5	fernandes, sandra raquel goncalves	Portucalense Infante D. Henrique University, Portugal	6	337	56.17	5	2012-23

Among the 841 institutions contributing to experiential learning in engineering education, only a few demonstrate sustained productivity and influence (Table 3). Aalborg University (Denmark) ranks first with 14 publications and the highest impact (742 citations, CPP = 53.00), reflecting its global reputation as a pioneer of problem- and project-based learning (PBL). Universidade do Minho (Portugal) also produced 14 publications with strong citation performance (504 citations, CPP = 36.00), underscoring Portugal's growing role in this research domain.

Beyond Europe, the Tecnológico de Monterrey (Mexico) contributed 14 publications but with lower citation impact (CPP = 16.93), highlighting emerging leadership from Latin America. Universidad Politécnica de Madrid (Spain) and the University of Michigan, Ann Arbor (USA) complete the top five, both with 9 publications, representing significant contributions from Southern Europe and North America.

Overall, while contributions are widely distributed across hundreds of institutions, intellectual leadership is concentrated in a small set of European universities, complemented by emerging activity in Latin America and the United States. This pattern indicates both global diffusion and regional hubs driving experiential learning research in engineering education.

Table: 3 Top 5 institutions

Rank	*Institution*	TP	TC	CPP	H	YA
1	aalborg university, aalborg, denmark	14	742	53.00	9	2011-23
2	universidade do minho, braga, portugal	14	504	36.00	9	2011-24
3	tecnológico de monterrey, monterrey, mexico	14	237	16.93	8	2011-24
4	universidad politécnica de madrid, madrid, spain	12	247	20.58	8	2015-24
5	university of michigan, ann arbor, ann arbor, united states	9	189	21.00	6	2013-24

The dataset includes contributions from 83 countries, reflecting the global spread of experiential learning research in engineering education. However, output and influence are concentrated in a few leading nations (Table 4).

The United States dominates with 207 publications and 4,148 citations, the highest h-index (32) and CPP (20.04) among the top producers. This confirms the USA's role as the global hub of engineering education research, supported by long-standing traditions of active learning and strong institutional networks.

India ranks second in productivity with 79 publications, but with lower citation impact (CPP = 18, h = 10), suggesting that while research activity is expanding rapidly, international visibility and influence are still developing.

Spain contributes 68 publications with strong scholarly impact (1,153 citations, CPP = 27, h = 19), reflecting its established focus on project-based and student-centered pedagogies. Australia follows with fewer outputs (33 publications) but demonstrates remarkable influence (1,079 citations, CPP = 33, h = 16), indicating highly cited contributions despite

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lower volume. Similarly, the United Kingdom has 32 publications but strong citation performance (648 citations, CPP = 32, h = 14), underscoring its reputation for high-quality, impactful studies in engineering pedagogy.

Overall, while 83 countries contribute to the field, intellectual leadership remains concentrated in a handful of advanced economies, particularly the USA and parts of Europe. Emerging economies such as India are expanding output, but citation impact lags behind, highlighting opportunities for stronger international collaboration and greater global integration.

Table: 4 Top 5 Countries

Rank	country	TP	TC	CPP	H	YA
1	United States	207	4148	56	32	2010-24
2	India	79	406	18	10	2014-24
3	Spain	68	1153	27	19	2011-24
4	Australia	33	1079	7	16	2011-24
5	United Kingdom	32	648	32	14	2010-24

3.4 Collaboration Networks

The co-authorship network (Figure 5) highlights the structure of collaborations among the 2,127 authors contributing to experiential learning research in engineering education. Despite the large pool of contributors, collaboration is concentrated in a few prominent clusters, with many authors publishing independently or in small groups.

The largest and most influential cluster is centered on Kolmos, Anette Jensen (Aalborg University, Denmark), whose extensive work on problem- and project-based learning has established Aalborg as a global hub. Kolmos collaborates closely with colleagues such as Du, Xiangyun (also Aalborg University), forming a strong Scandinavian-led network that is well integrated with other European and Asian researchers.

Another visible hub is formed around Fernandes, Sandra Raquel Gonçalves and colleagues from Portugal and Spain, reflecting the growing prominence of Iberian institutions in project- and curriculum-based approaches. Smaller but emerging clusters are observed in Asia and the Middle East, with authors such as Khalid, Md. Safiuddin and Chandran, M. linking engineering pedagogy with context-specific innovations in developing regions.

Overall, while the network demonstrates the presence of several well-connected leaders, the collaboration landscape is fragmented, with a large number of isolated authors and small clusters. This indicates that experiential learning research is still maturing as a global collaborative field. Strengthening cross-continental partnerships, particularly linking emerging research regions (e.g., India, Latin America) with established hubs in Europe and North America, could enhance knowledge exchange and raise the global impact of this domain.

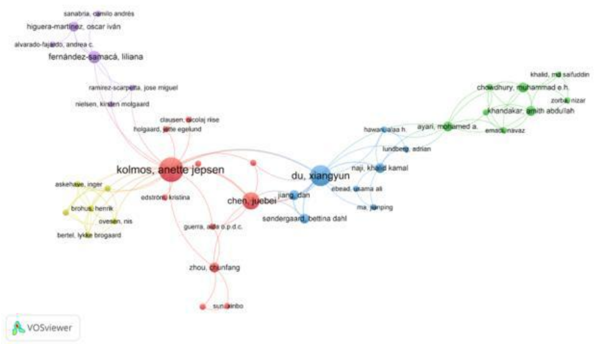

Fig. 5: Collaboration of Authors

The country co-authorship network (Figure 6) maps collaboration patterns among the 83 contributing nations, with only countries producing five or more publications included for clarity. The network is dominated by a few highly productive hubs, particularly the United States, which occupies the central position with extensive collaborative links to Europe, Asia, and Australia. This reflects its role as the leading global contributor in terms of both volume and citation impact.

Spain, the United Kingdom, and Germany form strong European nodes, frequently partnering with the United States as well as with regional neighbors such as Portugal and the Netherlands. This cluster illustrates the strength of intra-European collaboration, which has been instrumental in advancing project- and problem-based learning approaches.

In Asia, India emerges as a productive hub, collaborating actively with both Western countries and regional partners including Malaysia, China, and Singapore. While India contributes substantial output, its collaboration patterns indicate growing but still developing international integration. Australia appears as another active node, linking the Asia-Pacific region with Europe and North America.

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Smaller but significant contributors include United Arab Emirates, Saudi Arabia, and Qatar, reflecting rising research interest from the Middle East in engineering pedagogy and experiential learning. These countries often collaborate with Western partners, showing an outward-looking orientation.

Overall, while the network highlights several well-connected clusters, the distribution also shows asymmetry: a few leading nations (United States, Spain, India, UK, Australia) anchor the field, while many of the 83 participating countries remain peripheral with limited international partnerships. Strengthening South–South collaborations (e.g., between Asia, Latin America, and Africa) could enhance diversity and global representation in experiential learning research.

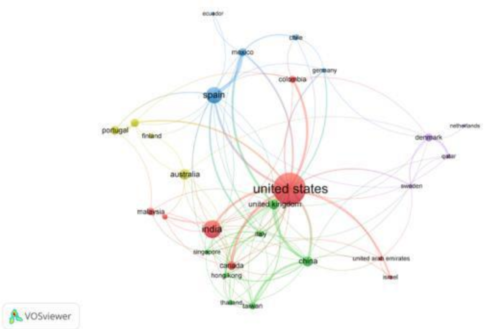

Fig. 6: collaboration of countries

IV. LIMITATIONS AND FUTURE DIRECTIONS

4.1 Limitations

This study has several limitations. First, the analysis relied solely on the Scopus database, which, while comprehensive, has inherent issues such as author name disambiguation (e.g., variations in spelling or formatting leading to duplicate or fragmented author records) and citation counts that differ from other databases like Web of Science or Google Scholar. Second, the bibliometric mapping is sensitive to keyword variations, including synonyms, spelling inconsistencies, and hyphenation (e.g., problem-based learning vs. problem-based learning), which may result in fragmented clusters or overlooked terms. Finally, restricting the dataset to English-language publications and the period 2010–2024 improves focus but inevitably excludes some earlier and non-English contributions.

4.2 Future Directions

Future research should aim to overcome these constraints by combining data from multiple bibliographic databases (e.g., Scopus, Web of Science, Google Scholar, ERIC) to cross-validate publication and citation metrics. Enhanced author profiling and disambiguation tools should be applied to reduce duplication or misattribution of scholarly outputs. Similarly, future studies should employ more robust keyword standardization, possibly through natural language processing (NLP) techniques, to minimize inconsistencies and better capture emerging terms. Expanding to multilingual datasets and extending the timeframe would further enhance coverage, while linking bibliometric insights with educational policy and curriculum reform practices could strengthen the practical relevance of this research.

V. CONCLUSION

This bibliometric study provides a comprehensive overview of experiential learning research in engineering education, mapping its growth, thematic directions, and global distribution. The analysis of 694 publications from 2010–2024 reveals a steady upward trend, with a marked acceleration after 2020 driven by digital transformation and the impact of the COVID-19 pandemic. Four dominant research clusters were identified: project- and problem-based learning, student engagement and perceptions, technology-enhanced approaches, and professional development with sustainability. Together, these themes demonstrate how experiential learning has evolved from traditional classroom reforms to encompassing digital and societal dimensions.

The findings show that research leadership is geographically concentrated. The United States remains the most productive and influential country overall, while European institutions, particularly Aalborg University in Denmark and the University of Minho in Portugal, anchor intellectual leadership through highly cited contributions. At the same time, emerging contributions from India, Spain, and Latin America highlight growing global interest. Collaboration networks, however, remain fragmented, with limited cross-continental ties and many isolated authors.

This study is subject to limitations, including reliance on a single database (Scopus), author name inconsistencies, variations in citation counts across databases, and challenges in keyword standardization. Future research should integrate multiple databases, expand to multilingual datasets, apply stronger author disambiguation tools, and explore thematic evolution

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through longitudinal and systematic analyses. Strengthening international collaboration and linking bibliometric insights with educational policy and curriculum reform will be essential to advancing experiential learning research and ensuring its impact on future engineering education practices.

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