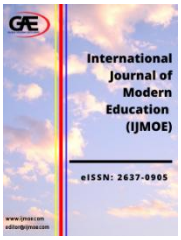
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RESEARCH TRENDS IN FLUID MECHANICS EDUCATION: A BIBLIOMETRIC ANALYSIS

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Abstract:

Fluid mechanics is a fundamental subject in engineering education, particularly in polytechnic and technical institutions where strong integration between theoretical understanding and practical application is required. Despite its importance, research related to fluid mechanics education remains scattered across different publication sources, themes, and countries, making it difficult to obtain a clear overview of its development. Therefore, this study aims to analyse the research trends in fluid mechanics education through a bibliometric approach using data retrieved from the Scopus database. A total of 7,415 documents were analysed using descriptive bibliometric indicators and visual mapping through VOSviewer. The analysis focused on annual publication trends, country contributions, keyword occurrence, source titles, productive authors, and co citation patterns by countries. The results show an overall upward trend in publication output, with the United States emerging as the dominant contributor in terms of productivity and citation influence. Keyword analysis revealed that the field is strongly centred on fluid mechanics, engineering education, students, curricula, and teaching, while the VOSviewer network further highlighted the growing presence of technology related themes such as computational fluid dynamics, e-learning, and computer aided instruction. In addition, the publication landscape is strongly supported by conference proceedings, especially in engineering education platforms. The main benefit of this paper is that it provides a structured overview of the intellectual development, thematic directions, and global research patterns of fluid mechanics education. The findings offer useful guidance for lecturers, researchers, and curriculum

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developers, particularly in polytechnic institutions, in identifying important teaching trends, strengthening instructional design, and exploring new research directions in fluid mechanics education.

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Keyword:

Bibliometric Analysis, Engineering Polytechnic Education, Fluid Mechanics, Scopus, VOSviewer

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Introduction

Fluid mechanics is a core subject in mechanical and civil engineering because it explains the behavior of liquids and gases in motion and at rest. It is essential in topics such as piping systems, pumps, turbines, hydraulics, and aerodynamics. In polytechnic education, students must understand both the theory and its practical applications. However, fluid mechanics is often seen as difficult because it involves abstract concepts, mathematical analysis, and visual understanding. Topics such as Bernoulli's principle, continuity equation, Reynolds number, and pressure loss can be challenging. To address this, educators use methods such as laboratory work, project-based learning, simulations, CFD software, animation, and interactive visualization.

Research on fluid mechanics education has expanded, covering curriculum design, practical learning, digital tools, problem based learning, and virtual laboratories. However, the studies are dispersed across journals, countries, and research areas, making the overall development of the field difficult to track. Bibliometric analysis provides a systematic way to examine publication trends, citation patterns, authorship, and keywords. In fluid mechanics education, it helps identify major themes, key contributors, and emerging directions. Therefore, this study conducts a bibliometric analysis of fluid mechanics education research using Scopus data. It examines publication trends, leading countries, authors, and journals, as well as dominant and emerging themes. This paper is significant because it provides a structured overview of scholarly development in fluid mechanics education and offers practical insights for lecturers, researchers, and curriculum planners. It is particularly relevant to polytechnic institutions that aim to improve engineering teaching practices through evidence based educational strategies.

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Literature Review

Engineering education has increasingly emphasized student centered learning, active engagement, and digital integration in the teaching of technically demanding subjects. Fluid mechanics is one of the engineering subjects that has attracted attention due to its conceptual complexity, and the difficulty students often experience when connecting theory with practical phenomena.

A considerable body of literature in engineering education has shown that students perform better when abstract scientific principles are supported by visual and experiential learning. In fluid mechanics, this includes demonstrations of flow behavior, use of transparent apparatus, simulation software, and experimental activities involving pressure measurement, flow rate analysis, and head loss observation. These approaches help students understand invisible flow phenomena that are otherwise difficult to imagine through equations alone.

Another important trend in literature is the use of computational tools. The integration of computational fluid dynamics into teaching has been reported as a useful strategy for improving conceptual understanding and exposing students to industrially relevant software environments. In addition, virtual laboratories and simulation-based learning have become more prominent, especially in response to the need for flexible and technology enhanced education.

Scholars have also highlighted the role of problem-based learning and project-based learning in engineering subjects. These approaches are aligned with the needs of polytechnic education because they encourage practical problem solving, teamwork, and application of theoretical principles. Within fluid mechanics education, such methods may involve pipeline system design, pump selection, hydraulic experiments, or analysis of real flow related engineering problems. Although these pedagogical developments are important, literature remains dispersed across multiple subfields including mechanical engineering education, science education, simulation-based instruction, and educational technology. As a result, there is limited synthesis of the overall development of fluid mechanics education research. Most studies focus on specific teaching interventions or classroom implementations rather than presenting a broad overview of publication patterns and thematic development.

Bibliometric studies have been widely used in other academic fields to map knowledge structures, identify influential works, and track research evolution. In engineering education, bibliometric analysis can provide valuable insights into how teaching related research has changed over time, what topics receive the most attention, and which areas remain underexplored. However, bibliometric investigations specifically focused on fluid mechanics education are still limited. This gap justifies the need for the present study.

Methodology Research Design

This study adopted a bibliometric research design to analyze scholarly publications related to fluid mechanics education. Bibliometric analysis is a quantitative method used to evaluate publication patterns, research productivity, citation structure, and thematic development within a particular field of study. The method is appropriate for identifying the intellectual structure and evolution of fluid mechanics education research.

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Data Source

The data for this study were retrieved from the Scopus database because it is one of the largest and most widely recognised abstract and citation databases for peer reviewed literature. Scopus was selected due to its broad coverage of journal articles, conference papers, and review documents across engineering and education fields of sustainable tourism is to reduce poverty, respect socio-cultural authenticity.

Search Strategy

The search was conducted using title, abstract, and keyword fields to ensure relevance to the topic. A possible search string is shown below:

TITLE-ABS-KEY ("fluid mechanics" AND education) OR TITLE-ABS-KEY ("fluid mechanics" AND teaching) OR TITLE-ABS-KEY ("fluid mechanics" AND learning) OR TITLE-ABS-KEY ("fluid flow" AND education) OR TITLE-ABS-KEY ("fluid dynamics" AND education)

Inclusion and Exclusion Criteria

To ensure data quality and relevance, the retrieved documents were screened according to the following criteria:

Inclusion Criteria

1. Documents related to fluid mechanics in educational contexts
2. Journal articles, conference papers, and review papers
3. Publications indexed in Scopus
4. Documents written in English
5. Publications within the selected time range

Exclusion Criteria

1. Studies related purely to fluid mechanics research without educational focus
2. Non-English publications
3. Errata, notes, editorials, and unrelated short communications
4. Duplicated records

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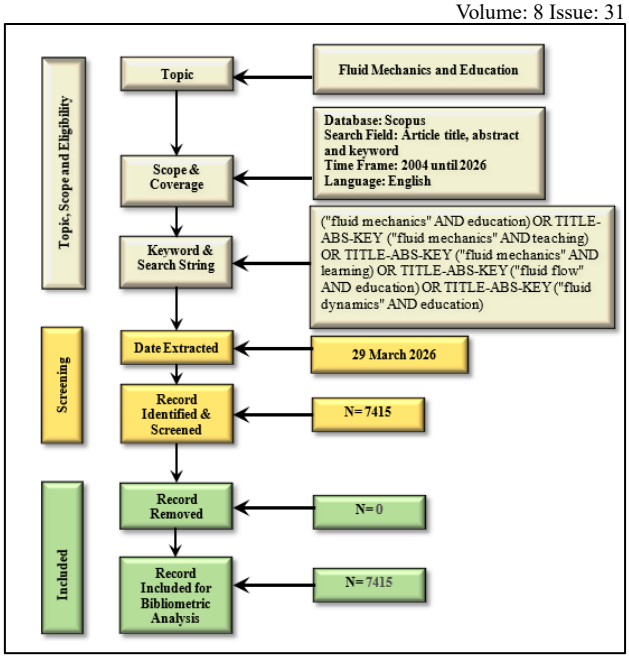


Figure 1: Workflow of Data Identification, Screening, and Inclusion for Bibliometric Analysis

Data Collection Procedure

The bibliographic information was exported from Scopus in CSV format. The exported data included authors, title, year of publication, source title, affiliations, country, abstract, citations, and keywords. The dataset was then cleaned by removing duplicate and irrelevant records before analysis.

Data Analysis

The cleaned dataset was analyzed using descriptive bibliometric indicators and visual mapping. The analysis focused on:

- Annual publication trends
- Most productive authors
- Most influential journals or source titles
- Country contributions
- Keyword co-occurrence analysis
- Citation analysis
- Thematic cluster visualization

VOSviewer was used to generate keyword co-occurrence maps and network visualizations. The software allows the identification of research clusters based on keyword relationships, thus helping to reveal dominant themes and emerging topics in fluid mechanics education.

Research Framework

The research framework of this study consists of four main stages:

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Data retrieval from Scopus

- Screening and cleaning of bibliographic records
- Bibliometric analysis using descriptive indicators
- Visualization and interpretation using VOSviewer

Results and Discussion

Overview of Publication Output

The Scopus search retrieved a total of **7,**415 documents related to fluid mechanics education. This total indicates that the topic has attracted substantial scholarly attention and reflects the established role of fluid mechanics within engineering and technical education research. The large number of publications suggest that fluid mechanics education is not a marginal topic, but rather a mature and continuing area of discussion within engineering pedagogy.

However, it should also be noted that the annual values displayed in Figure 2 represent the publication figures for the years shown in the figures only. Therefore, the values in the graph should be interpreted as the visible yearly trend from the selected period, while the total of 7,415 documents reflects the overall Scopus retrieval.

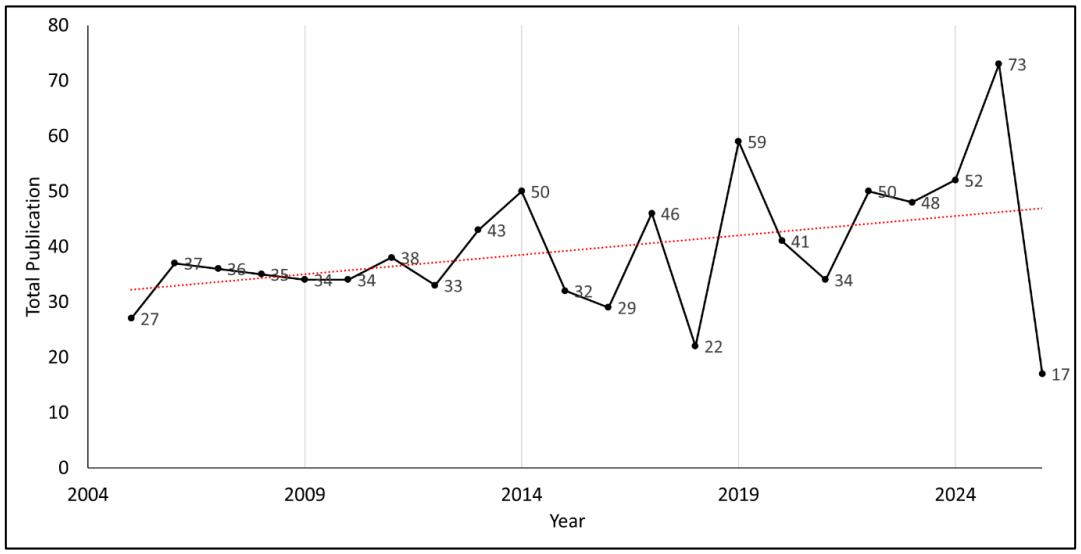


Figure 2: Annual Publication Trend of Fluid Mechanics Education Research Indexed in Scopus

Annual Publication Trend

The yearly publication trend in Figure 2 shows that research on fluid mechanics education has generally increased over time, although the pattern is not strictly linear. The red dotted trendline in Figure 2 confirms an overall upward direction, indicating gradual growth in scholarly interest across the observed years. At the beginning of the period shown, the publication count was 27 documents in 2005, which later increased to 37 documents in 2006. This represents an increase of 37.0% within one year. From 2006 to 2011, the output remained relatively stable, fluctuating within the range of 34 to 38 publications, which suggests a consistent but moderate research

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presence during the early development stage of the field. A stronger rise became visible after 2012. As shown in Figure 1, publications increased from 33 documents in 2012 to 43 documents in 2013, followed by 50 documents in 2014. This indicates that fluid mechanics education began attracting greater attention, possibly due to the expansion of digital teaching technologies, simulation based learning, and stronger emphasis on engineering pedagogy.

The trend also shows several fluctuations. For example, the count dropped from 50 publications in 2014 to 32 in 2015, and further to 29 in 2016. A similar decline appears in 2018, when output fell to 22 publications, compared to 46 publications in 2017. Despite these temporary reductions, the field recovered quickly. In 2019, the number rose sharply to 59 publications, representing a 168.2% increase compared to 2018. This sudden growth suggests renewed research interest and possibly the increasing integration of innovative teaching strategies into fluid mechanics instruction. The most notable rise appears in the final years

shown. According to Figure 1, publication output reached 50 in 2022, 48 in 2023, 52 in 2024, and peaked at 73 publications in 2025. The increase from 52 in 2024 to 73 in 2025 represents a 40.4% growth, which is a strong indication that this research area continues to gain momentum. The decline to 17 publications in 2026 should be interpreted cautiously, as this is likely to reflect an incomplete publication year rather than an actual drop-in research activity.

Overall, Figure 2 demonstrates that fluid mechanics education has experienced long term growth, supported by a positive trendline and higher output in recent years than in the earlier period. This pattern indicates that the field is evolving from a traditional teaching concern into a more active research domain linked to curriculum development, student learning, digital tools, and engineering education reform.

Country Contribution

The geographical distribution of publications shown in Table 1 reveals a highly concentrated pattern of research productivity. The United States is the leading contributor with 670 publications, accounting for approximately 9.04% of the total 7,415 documents. This contribution is far higher than any other individual country listed in Table 1, indicating the dominant role of the United States in shaping the discourse on fluid mechanics education.

The second highest entry in Table 1 is Undefined, with 145 publications or 1.96% of the total. This category most likely represents records with incomplete or unassigned country information. Excluding this category, China ranks second among clearly identified countries with 68 publications, contributing 0.92% of the total dataset. It is followed by the United Kingdom with 38 publications or 0.51%, and Spain with 33 publications or 0.45%.

The next group of contributing countries includes Canada and Germany, each with 28 publications or 0.38%, followed by France with 23 publications or 0.31%, Australia with 22 publications or 0.30%, and India with 21 publications or 0.28%. These values suggest that the research landscape is strongly led by developed nations with well-established engineering education systems, extensive academic infrastructure, and active publication cultures.

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Table 1: Top 20 Contributing Countries In Fluid Mechanics Education Research

Country	TP	%
United States	670	9.04%
Undefined	145	1.96%
China	68	0.92%
United Kingdom	38	0.51%
Spain	33	0.45%
Canada	28	0.38%
Germany	28	0.38%
France	23	0.31%
Australia	22	0.30%
India	21	0.28%
Portugal	18	0.24%
Indonesia	15	0.20%
Brazil	12	0.16%
Malaysia	11	0.15%
Mexico	10	0.13%
Switzerland	10	0.13%
Turkey	8	0.11%
Taiwan	7	0.09%
United Arab Emirates	7	0.09%

From a regional perspective, Table 1 also shows meaningful contributions from developing and emerging countries. For example, Indonesia recorded 15 publications, Malaysia contributed 11 publications, and United Arab Emirates produced 7 publications. Although the percentages are comparatively small, these results are still important because they indicate that fluid mechanics education is receiving attention in countries where technical and polytechnic education plays an important role in workforce development. The difference between the United States and other countries is substantial. For example, the United States produced almost 9.9 times more publications than China and approximately 17.6 times more than the United Kingdom. This dominance may reflect stronger investment in engineering education research, wider conference participation, and more active publication in discipline specific educational venues. At the same time, the presence of countries from Asia, Europe, Latin America, and the Middle East shows that interest in fluid mechanics education is globally distributed, even if uneven in scale.

Overall, Table 1 indicates that the research field is international in nature, but its productivity is concentrated in a relatively small group of countries. This finding suggests the need for broader participation from polytechnic institutions and technical education systems in underrepresented regions, especially in Southeast Asia and other developing contexts.

Keyword Analysis

The keyword distribution in Table 2 provides important insight into the conceptual structure of the field. The most frequent keyword is Fluid Mechanics, with 854 occurrences, which

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represents approximately 11.52% of the total number of documents. This is expected, as it is the central subject of the study. The second most frequent keyword is Engineering Education, with 787 occurrences or 10.61%, followed by Students with 605 occurrences or 8.16%. These three terms show that the literature is strongly positioned at the intersection of technical content, pedagogical context, and learner center focus.

Table 2: Most Frequently Occurring Keywords In Fluid Mechanics Education Research

Keywords	TP	%
Fluid Mechanics	854	11.52%
Engineering Education	787	10.61%
Students	605	8.16%
Curricula	334	4.50%
Teaching	297	4.01%
Education	247	3.33%
Thermodynamics	143	1.93%
Heat Transfer	140	1.89%
Computational Fluid Dynamics	103	1.39%
Learning Systems	92	1.24%
Problem Solving	84	1.13%
Mechanical Engineering	79	1.07%
Laboratories	76	1.02%
Project Management	66	0.89%
Education Computing	65	0.88%
Mechanics	62	0.84%
Professional Aspects	60	0.81%
E-learning	57	0.77%
Fluid Dynamics	48	0.65%
Design	47	0.63%
Undergraduate Students	40	0.54%
Engineering Research	37	0.50%
Computer Simulation	35	0.47%
Hydraulics	35	0.47%

The next most frequent keywords in Table 2 are Curricula with 334 occurrences (4.50%) and Teaching with 297 (4.01%), showing strong attention to course design and instructional delivery. Education also appears prominently with 247 occurrences, confirming that the dataset is center on pedagogy rather than purely technical fluid mechanics' research. Related engineering subjects such as Thermodynamics (143) and Heat Transfer (140) also appear, suggesting that fluid mechanics education is often discussed within integrated engineering curricula. Technology related terms occur less frequently. Computational Fluid Dynamic appears 103 times, while Computer Aided Instruction, Computer Software, and Computer Simulation appear 44, 43, and 35 times, respectively. This suggests that digital and simulation-based tools are present but not yet dominant. Learner focused terms such as Learning Systems (92), Problem Solving (84), Laboratories (76), E-learning (57), and Undergraduate Students (40)

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further show attention to student learning and instructional environments. Overall, the keyword pattern suggests four main dimensions in fluid mechanics education research: disciplinary content, curriculum and teaching, student learning, and digital support tools. The field remains strongly discipline based, although educational innovation is becoming more visible.

Source Title Analysis

The most productive publication outlets shown in Table 3 indicate that fluid mechanics education research is disseminated mainly through conference proceedings, followed by specialized journals in engineering education. The leading source is ASEE Annual Conference and Exposition Conference Proceedings, with 295 publications, representing approximately 3.98% of the total dataset. The second highest source is ASEE Annual Conference Proceedings, with 118 publications or 1.59%. Together, these two outlets contributed 413 publications, which is about 5.57% of the total documents.

Table 3. Leading Source Titles Publishing Fluid Mechanics Education Research

Source Title	TP	%
ASEE Annual Conference and Exposition Conference Proceedings	295	3.98%
ASEE Annual Conference Proceedings	118	1.59%
International Journal of Engineering Education	36	0.49%
ASME International Mechanical Engineering Congress and Exposition Proceedings Imece	30	0.40%
International Journal of Mechanical Engineering Education	22	0.30%
Proceedings Frontiers in Education Conference Fie	20	0.27%
Applied Mechanics and Materials	19	0.26%
American Society of Mechanical Engineers Fluids Engineering Division Publication Fedsm	17	0.23%
Proceedings Frontiers in Education Conference	17	0.23%
American Society of Mechanical Engineers Fluids Engineering Division Publication FED	15	0.20%
Chemical Engineering Education	14	0.19%
Proceedings of the ASME Turbo Expo	13	0.18%
Computer Applications in Engineering Education	12	0.16%
Journal of Engineering Education	11	0.15%
Journal of Physics Conference Series	11	0.15%
Proceedings of the National Conference on Fluid Power Annual Meeting	10	0.13%
Journal of Professional Issues in Engineering Education and Practice	8	0.11%
Education for Chemical Engineers	7	0.09%
European Journal of Physics	7	0.09%

The strong concentration of ASEE related proceedings suggests that fluid mechanics education has a clear conference-based publication culture. Teaching innovations, classroom practices, and curriculum developments are often shared at conferences before appearing in journals.

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Among journals, the International Journal of Engineering Education is the most productive source with 36 publications, followed by the International Journal of Mechanical Engineering Education with 22. Other notable journals include Chemical Engineering Education (14), Computer Applications in Engineering Education (12), and the Journal of Engineering Education (11).

Table 3 also shows strong contributions from professional engineering outlets. The ASME International Mechanical Engineering Congress and Exposition Proceedings recorded 30 publications, while the American Society of Mechanical Engineers Fluids Engineering Division contributed 17 and 15 documents in two related entries. This indicates that fluid mechanics education is discussed in both engineering education platforms and discipline specific professional communities. Overall, the publication pattern shows that the field is interdisciplinary, linking engineering education with fluid and mechanical engineering practice. Overall, Table 3 indicates that the field is strongly practice oriented, highly conference driven, and supported by a smaller but important group of established journals. This publication pattern suits the nature of fluid mechanics education, where teaching interventions, laboratory designs, and learning tools are often first disseminated in conference settings.

Author Productivity

The most productive authors in Table 4 show that the field has several recurring contributors, although no single author dominates the literature to a very large extent. The top entry is [No Author ID found] with 26 publications. Since this category does not represent an identifiable researcher, it should be interpreted as a metadata limitation rather than an actual author contribution.

Table 4: Most Productive Authors In Fluid Mechanics Education Research

Author Name	TP	%
[No Author ID found]	26	0.35%
Van Wie, B.J.	18	0.24%
Thiessen, D.B.	14	0.19%
Dutta, P.	10	0.13%
Ayala, O.M.	9	0.12%
Guedes, A.	9	0.12%
Morais, C.	9	0.12%
Soares, F.	9	0.12%
Adesope, O.	8	0.11%
Farrell, S.	8	0.11%
Ghosh, A.	8	0.11%

Van Wie, B.J. is the most productive author with 18 publications (0.24%), followed by Thiessen, D.B. with 14 (0.19%) and Dutta, P. with 10 (0.13%). Ayala, O.M., Guedes, A., Morais, C., and Soares, F. each recorded 9 publications, while Adesope, O., Farrell, S., Ghosh, A., and Leão, C.P. each contributed 8. These relatively low counts indicate that the field is broad and not dominated by a few authors. Instead, fluid mechanics education research is shaped by a wide network of scholars across different subthemes, including laboratory

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instruction, computational learning tools, concept-based teaching, and student center engineering education. Overall, Table 4 reflects a moderately distributed and collaborative research field, supported by a consistent group of active contributors.

Taken together, Figure 1 and Tables 1 to 4 show that fluid mechanics education is a growing research field. Publication output has increased over time, with the United States leading in productivity. The keyword structure shows a strong educational focus on students, teaching, and curricula, while also highlighting the growing role of digital and active learning approaches. The source title pattern indicates that the field is strongly conference driven and practice oriented. Author productivity also suggests that the field is broad and collaborative. Overall, the findings confirm that fluid mechanics education is an active research area with clear value for polytechnic and engineering education.

Keyword Co-occurrence Analysis Using VOSviewer

To further strengthen the bibliometric interpretation, the keyword co-occurrence network was analyzed using VOSviewer. The visualization shown in Figure 3 maps the conceptual structure of fluid mechanics education research based on the frequency of keyword appearance and their relational strength. In this network, larger nodes indicate more frequent keyword occurrence, while denser connecting lines indicate stronger relationships between terms.

Overall, Figure 3 confirms that the field is strongly centered on the interaction between disciplinary knowledge and educational practice. The most dominant keyword is fluid mechanics with 854 occurrences and a total link strength of 3461, followed by engineering education with 787 occurrences and 3377 total link strength, and students with 605 occurrences and 2941 total link strength. These three high frequency terms form the main conceptual core of the network and show that literature is primarily focused on how fluid mechanics is taught and learned in engineering contexts.

The structure of Figure 3 suggests several major thematic groupings. Figure 3 shows that fluid mechanics education research is mainly built around several connected themes. The strongest cluster focuses on education and teaching, reflected by high frequency keywords such as fluid mechanics, engineering education, students, curricula, teaching, and education. This indicates that the field is strongly centered on pedagogy, curriculum design, instructional delivery, and student outcomes.

A second theme links fluid mechanics with supporting engineering science subjects such as thermodynamics, heat transfer, mechanical engineering, mechanics, fluid dynamics, and hydraulics. This suggests that fluid mechanics education is commonly discussed within broader and integrated engineering curricula.

Figure 3 also highlights the growing role of digital and simulation-based learning. Keywords such as computational fluid dynamics, learning systems, computer aided instruction, computer software, computer simulation, e-learning, and educational computing show that technology supported teaching is becoming increasingly visible in the field. Another important theme concerns student center learning and performance. Terms such as problem solving, laboratories, student learning, student performance, active learning, undergraduate students, and surveys suggest strong attention to how students engage with different teaching approaches and practical learning environments. Lastly, several keywords point to application based and

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contextual engineering themes, including aerodynamics, flow of fluids, flow visualization, Reynolds number, wind tunnels, design, and shore protection. Although less frequent, these terms show that the field also addresses real engineering applications, strengthening its practical relevance.

Interpretation Of Keyword Relationships

The network density in Figure 3 and Table 5 shows that the keywords are highly interconnected rather than separated into isolated themes. This suggests three important interpretations:

1. Fluid mechanics education is multidisciplinary The field combines subject content, pedagogy, digital tools, and learner center research.
2. Teaching and learning remain the dominant focus Keywords such as engineering education, students, curricula, and teaching are more prominent than narrowly technical terms.
3. Technology enhanced learning is growing the appearance of computational fluid dynamics, e-learning, computer aided instruction, and computer simulation indicates an increasing shift toward modern teaching approaches.

From a discussion perspective, Figure 3 supports the earlier findings from Table 2, but it goes further by showing how the keywords are connected to one another. While Table 2 presents frequency counts, Figure 3 reveals the intellectual structure of the field. In other words, the keyword network confirms that fluid mechanics education is not limited to textbook based content delivery. Instead, it has developed into a broader educational domain involving curriculum design, student engagement, practical learning, and digital innovation.

In summary, the VOSviewer analysis shown in Figure 2 demonstrates that research in fluid mechanics education is organized around a strong pedagogical core, supported by engineering science content and increasingly influenced by simulation and educational technology. This makes the field highly relevant for polytechnic institutions, where effective teaching must combine conceptual understanding, practical application, and student center instructional methods.

Table 5: Keyword Co-Occurrence Network

Id	Keyword	Occurrences	Total Link Strength
84	active learning	29	109
134	aerodynamics	33	145
726	chemical engineering	27	108
781	civil engineering	30	132
986	computational fluid dynamics	103	489
1023	computer aided instruction	44	232
1057	computer simulation	35	135
1058	computer software	43	243
1148	contacts (fluid mechanics)	42	205
1339	curricula	334	1819
1376	data acquisition	25	143
1456	design	47	240

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1615	discharge (fluid mechanics)	25	40
1644	distance education	26	126
1730	e-learning	57	291
1764	education	247	1190
4029	mathematical models	34	172
4085	mechanical engineering	79	401
4089	mechanical engineering curriculum	29	179
4117	mechanics	62	362
4879	personnel training	27	128
5155	problem solving	84	456
5198	professional aspects	60	344
5239	project management	66	379
5548	Reynolds number	28	109
6451	technical presentations	40	249
6522	textbooks	27	152
6598	thermodynamics	143	761
6844	undergraduate students	40	206
7244	wind tunnels	30	150

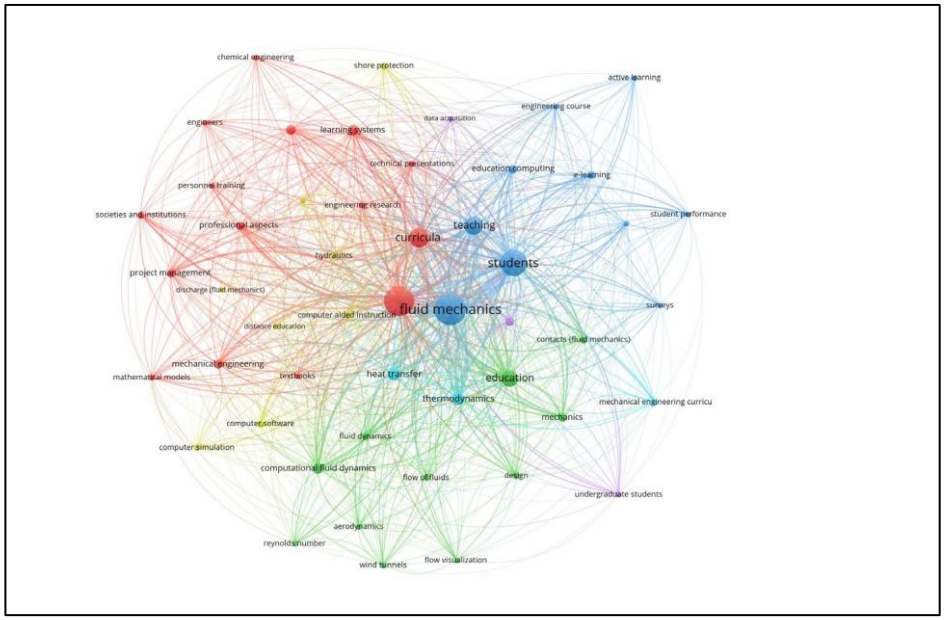


Figure 3. Keyword Co Occurrence Network of Fluid Mechanics Education Research Generated Using VOSviewer

Co citation Analysis by Countries

In addition to keyword relationships, co- citation analysis by countries provides insight into the geographical structure of scholarly influence in fluid mechanics education research. The VOSviewer network in Figure 4 shows citation connections among countries based on documents, citations, and total link strength. Larger nodes indicate stronger research presence, while connecting lines represent citation relationships. As shown in Figure 4, the United States is the most central and dominant country in the network, with 670 documents, 5,202 citations,

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and the highest total link strength of 32. This shows that the United States is both the most productive and the most influential contributor, serving as the main knowledge hub in the field. The United Kingdom is the second most influential country in terms of citations, with 38 documents and 728 citations, although its total link strength is only 4. This suggests strong citation impact but lower network centrality. China follows with 69 documents, 263 citations, and a total link strength of 8, indicating stronger citation linkage than several European countries despite having fewer citations than the United Kingdom.

Other countries shown in Figure 3 include:

- Canada with 28 documents, 349 citations, and total link strength of 4
- Germany with 28 documents, 235 citations, and total link strength of 4
- France with 23 documents, 118 citations, and total link strength of 4
- Spain with 33 documents, 137 citations, and total link strength of 1

These results indicate that several countries contribute meaningfully to the field, but their citation connectivity remains relatively modest compared to the United States. In particular, Spain shows a comparatively weak connection structure, as reflected by its total link strength of only 1, suggesting limited integration into the broader co citation network.

It should also be noted that terms such as ASME, engineering, and technology appear in the network with measurable citation values. These entries most likely reflect metadata or indexing irregularities rather than actual countries. Even so, they form part of the mapped citation environment and indicate the presence of publication or source related citation patterns in the dataset.

From an interpretive perspective, Figure 3 reveals three important points:

1. The United States is the dominant citation hub
   Its citation count of 5,202 is substantially higher than all other entries, and its total link strength of 32 confirms strong international citation connectivity.
2. Citation impact and network connectivity are not always the same
   For example, the United Kingdom has high citations, while China shows stronger link connectivity relative to its citation count.
3. The field remains internationally distributed but unevenly connected
   Although several countries appear in the co citation map, the network is still concentrated around one major center, namely the United States.

Overall, the co-citation network in Figure 4 shows that fluid mechanics education research is globally visible, but its intellectual influence is strongly concentrated in a few leading countries. This pattern is consistent with the earlier country productivity findings in Table 1 and table 6, where the United States also emerged as the dominant contributor. Thus, Figure 4 strengthens the conclusion that the international development of fluid mechanics education is led by a small group of countries, with the United States serving as the main reference point in the global citation landscape.

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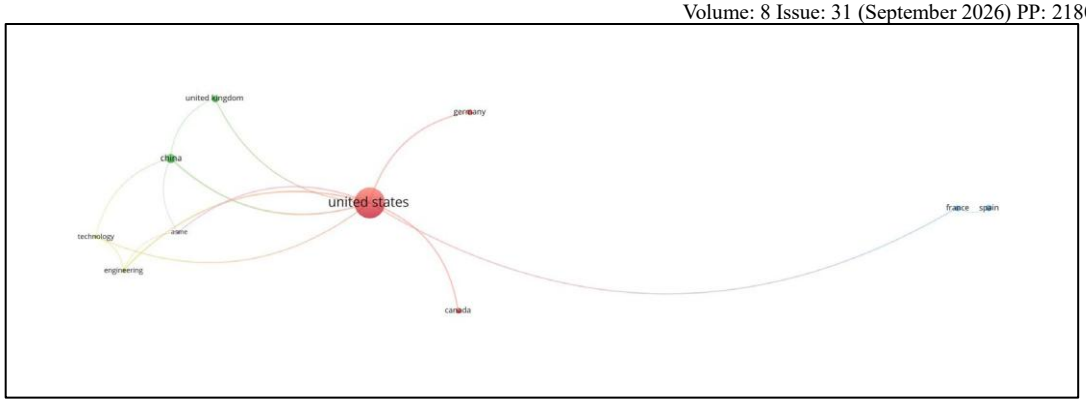


Figure 4. Co Citation Network Of Contributing Countries In Fluid Mechanics Education Research Generated Using VOSviewer

Table 6: Co Citation Network with Countries

Id	Country	Documents	Citations	Total Link Strength
16	asme	5	34	6
26	Canada	28	349	4
29	China	69	263	8
46	engineering	13	41	9
53	France	23	118	4
56	Germany	28	235	4
118	Spain	33	137	1
125	technology	6	32	6
137	united kingdom	38	728	4
138	united states	670	5202	32

Conclusion

This study presented a bibliometric analysis of research trends in fluid mechanics education using Scopus indexed publications. The findings show that fluid mechanics education has become an active area within engineering education research, with publication output increasing over time. The field is led mainly by the United States, followed by countries such as China, the United Kingdom, Canada, and Germany. Keyword and VOSviewer analyses revealed a strong pedagogical focus on students, teaching, curricula, and engineering education, alongside related disciplinary and technological themes. The results also show that the field is strongly conference driven, reflecting its practical and innovation-oriented nature. Overall, this study provides a useful overview of the development, dominant themes, and global research patterns of fluid mechanics education, particularly for supporting curriculum improvement, teaching strategies, and future research in polytechnic and engineering education.

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