Qualitative and Quantitative Methods in Libraries (QQML) 14,4:621-646, 2025

Twenty-Four Years of Science Process Skills Research: A Quantitative Scientometric Assessment (2000–2024)

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Abstract: This scientometric analysis examines 8,110 Scopus articles (2000-2024) tracking the evolution of Scientific Process Skills (SPS) research. Publication output showed steady growth, reaching a peak of 730 articles in 2024, indicating expanding academic engagement. Teece's 2007 work received the highest citations (8,386), demonstrating substantial cross-disciplinary impact. Keyword analysis revealed enduring themes like "education" and "learning" alongside emerging interests in artificial intelligence integration and pandemic-related pedagogical adaptations. The strongest research collaborations existed between North American and European institutions. These findings highlight key trends including the growing incorporation of technology in SPS pedagogy, significant geographical disparities in research output, and important opportunities for enhanced global cooperation. The study provides empirical evidence of SPS research development, offering science educators and policymakers critical insights for developing twenty-first-century competencies through evidence-based approaches that address current educational challenges and technological advancements.

Keywords*:* science process skills, scientometric analysis, research trends, education,

Received: 25.9.2025 Accepted: 4.12.2025 ISSN 2241-1925

Introduction

Scientific process skills are crucial competencies that students must develop to participate effectively in scientific research and problem-solving. These skills include various cognitive and manipulative talents that allow learners to generate inquiries, perform experiments, and evaluate results. They are essential for creating a profound comprehension of scientific principles and for enhancing critical thinking and analytical skills. The critical nature of scientific process skills is emphasized by various educational approaches and standards. Bybee (1997) asserts that these skills provide the foundation of scientific literacy, defined as the capacity to utilize scientific knowledge and processes in daily life. The National Science Education Standards underscore the necessity of incorporating science process skills into the curriculum to improve students' understanding and acceptance of science (National Research Council, 1996).

Scientific process skills can be generically classified as fundamental and integrated abilities. Fundamental science process skills encompass observation, classification, measurement, communication, inference, and prediction. These skills are generally introduced at the elementary level and serve as a basis for more complex work. Integrated science process skills, encompassing higher-order thinking, consist of hypothesis formulation, variable identification, experimental design, and data interpretation. These competencies are crucial for executing scientific inquiries and are often cultivated during secondary education (Padilla, 1990). The development of science process skills is impacted by multiple elements, such as instructional quality, the learning environment, and resource availability. Effective teaching methods in science, including inquiry-based learning and experiential experiments, have demonstrated a substantial improvement in students' science process skills (Hofstein & Lunetta, 2004). Moreover, access to well-equipped laboratories and technology instruments can enhance the practical application of these skills, therefore increasing students' overall scientific ability. The theoretical implication is that SPS are no longer viewed solely as pedagogical goals for scientific literacy but as core competencies for a 21st-century workforce. This represents a significant

instrumental turn in the philosophy of science education, where the value of SPS is justified by their economic impact rather than solely by their role in fostering enlightened citizenship.

Recent studies have emphasized the significance of educator professional growth in cultivating science process abilities in learners. Teachers trained in inquiry-based methodologies and assessment strategies are more adept at designing learning experiences that foster skill development (Supovitz & Turner, 2000). Further, continuous professional development enables educators to remain informed about the latest pedagogical methods and technological innovations, thereby enhancing the educational experience. Science process skills are essential for pupils to succeed in science education and their capacity to participate in scientific research. These skills facilitate the learning of scientific knowledge while also enhancing problem-solving and critical thinking capabilities. Therefore, it is essential for educators to emphasize the cultivation of science process skills via effective pedagogical tactics, sufficient resources, and ongoing professional development. In doing so, they may ensure that students are adequately equipped to handle the intricacies of the scientific realm and contribute greatly to society. The development of science process skills is a foundational element of scientific education and practice. This align with the view that 'learning processes and the nature of managerial coordination are critical' for building competitive advantage in knowledge intensive field (Teece, 2014).

The scientometric analysis of SPS employs quantitative techniques to examine the literature in this domain, revealing trends, patterns, and influences. This analysis elucidates the evolution and distribution of research on SPS, offering significant information for educators, policy makers, and academics. Scientometric techniques, including bibliometric analysis, collaboration analysis of networks, and citation analysis, provide a comprehensive survey of the

research scene in SPS.

Scientometric study SPS offers a comprehensive overview of the field's evolution by identifying pivotal patterns, collaborative networks, and significant studies. This knowledge is essential for enhancing successful teaching and learning methodologies in science education as well as directing future research trends. Scientometric studies provide an accurate method for assessing evolution and trends within particular scientific fields. Scientific process skills (SPS), encompassing observation, classification, measurement, inference, and prediction, constitute vital competences for scientific investigation and teaching. The utilization of scientometric methodologies to examine SPS has yielded significant insights into the development, instruction, and evaluation of these skills across a variety of educational settings.

Collaboration patterns among archers offer significant insights into the mechanics of SPS research. Scientometric analyses indicate that collaborative research, particularly multinational partnerships, generally yields more influential publications. This is demonstrated in the research conducted by Dori and Belcher (2005), researchers examined the efficacy of project-based learning in fostering SPS through collaborative initiatives among teachers and researchers from various nations. Their research illustrated the advantages of cross-cultural viewpoints in enhancing the comprehension and instruction of SPS. Scientometric science process skills provide a thorough analysis of the field's evolution, emphasizing significant patterns, impactful research, and prospective trajectories. Utilizing diverse scientometric techniques, researchers can reveal significant trends and insights that enhance the progression of SPS instruction. The ongoing investigation into scientometric information will be essential for recognizing new trends and meeting the changing demands of scientific education in the 21st century.

Review of Literature

Xie, Zhang, and Lai (2019) performed a bibliographic review and observed a consistent rise in publications about SPS from 2000 to 2018, indicating an escalating interest in enhancing SPS education. Zhao, Tang, and Wang (2020) employed co-authorship analysis of networks to illustrate significant worldwide cooperation among academics from various nations, underscoring the global acknowledgment of the significance of SPS. An study of citations in SPS research uncovers significant studies and emerging patterns. Prominently referenced publications frequently emphasize novel pedagogical approaches, evaluative strategies, and curriculum amalgamation. Lederman, Lederman, and Antink (2013) notably impacted the field with their research on evaluating SPS in both primary and secondary schools pupils, highlighting the necessity for efficient SPS evaluation techniques.

Padilla, Okey, and Garrard (1984) established the foundation for comprehending the evaluation and enhancement of SPS in pupils. Their research underscored the significance of these abilities in promoting scientific reasoning and inquiry-based education, while the resolution of SPS research may be analyzed by many scientometric metrics, including publication frequency, citation analysis, and collaboration networks.Tsai and Wen (2005) conducted a study employing citation analysis to assess the influence of SPS-related studies published in science education journals. Research indicated that papers emphasizing experimental and inquiry-based methodologies for teaching SPS garnered greater citations, reflecting significant interest and endorsement from the scientific community. Comprehensive analysis in scientometric research has unveiled trends and movements in research emphasis throughout time. In recent times, there has been an increasing focus on the integration of modern technology with SPS instruction. Researchers such as Hofstein and Lunetta (2004) studied the application of digital technologies and simulations to improve student engagement and competence in SPS. Their findings suggest that technology-enhanced educational settings can significantly enhance

students' ability to conduct scientific inquiries and develop skills in higher-order thinking. Another critique of the scientometric study on SPS is the recognition of research gaps and prospective directions. Shavelson and Huang (2003) emphasised the necessity for additional study on the evaluation of SPS in practical environments, extending beyond conventional classroom contexts. They emphasised the need for creating dependable and valid evaluation instruments that can capture the complexities of learners' scientific thinking and problem-solving abilities.

Objective

1. To identify scientific production of the literature from 2000 to 2024
2. To find out the affiliation-wise contribution of the literature
3. To know country-wise scientific production over time.
4. To measure the most globally cited documents
5. To explore the most frequently used keyword
6. To assess the most trending topic in the field of science process skills research
7. To evaluate the top countries' collaboration network in the field of science process skills research.
8. To identify the top 10^{th} core source in the field of science process skills research by Bradford's Law.

METHODOLOGY

Research Design

A quantitative research method is taken up for this study where the data was collected from Scopus database during the year 2000-2024 through the search keywords science process skills for search query. Scopus database was used for data collection due to rigorous peer-reviewed high visibility to a global academic audience, and valuable ciatation metric, this ensures quality and maximizes research impact. To get reliable and specific information the document available in articles form was selected and limited to English

Year	Articles

language only and the term 'science process skills' was used for shortlisting the document to get most of the literature related to science process skills.The data was extracted in csv file and analyzed using Bibliometric analysis tools Biblioshiny and VOSviewer.

Results

1. Annual scientific production of the articles published between the years 2000-2024.

The give below table and figure below show year-wise publication pattern in field of science process skills.

Table 1. Annual scientific production between the years 2000-2024

2000	114
2001	157
2002	167
2003	137
2004	75
2005	98
2006	128
2007	170
2008	174
2009	246
2010	233
2011	252
2012	292
2013	378
2014	349
2015	293
2016	292
2017	336
2018	403
2019	498
2020	600
2021	645
2022	666
2023	677
2024	730
Total	**8110**

Figure 1. Annual scientific production between the years 2000-2024

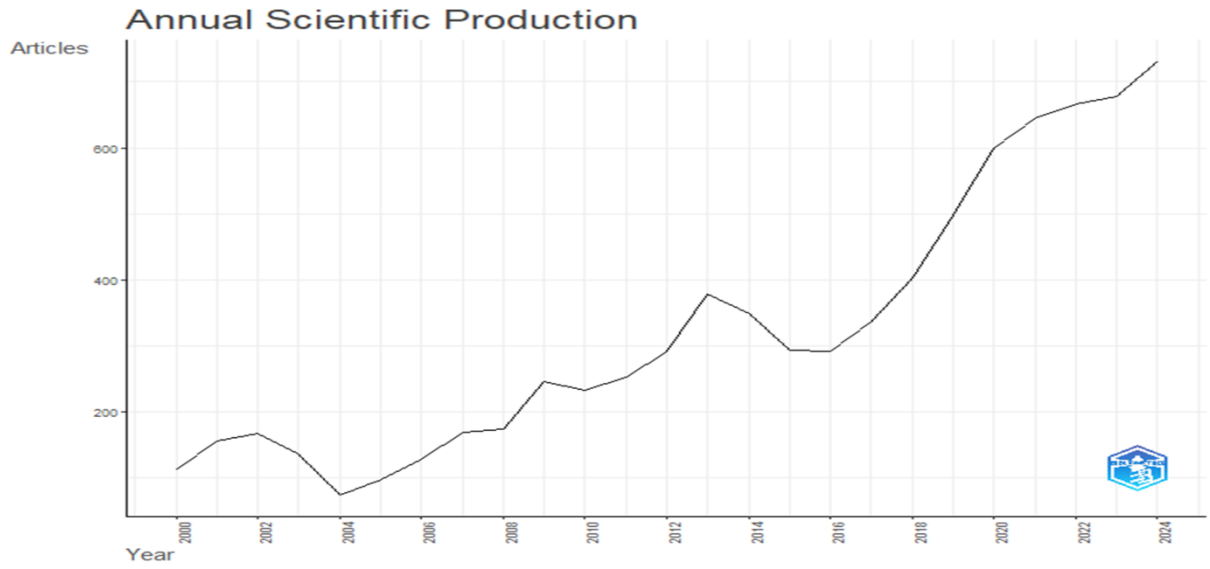


Table 1 and Figure 1 show the annual scientific production of the articles published between the year 2000 and 12th December 2024. The data shows that a total number of 114 (1.40%) articles was published in the year 2000, while a total number of 157 (1.93%) articles was found to be published in the year 2001. In the year 2002, a total of 167 (2.05%) articles were published and a total number of 137 (1.68%) were published in the year 2003. 75 (0.92%) articles were published in the year 2004, whereas in the year 2005, a total number of 98 (1.20%) articles were found to be published. In the year 2006, a total number of 128 (1.57%) articles were published and 170 (2.09%) numbers of articles were found to be published in the year 2007. A total number of 174 (2.14%) articles were found to be published in the year 2008 and in the year 2009, a total of 246 (3.03%) literature were found to be published. In the year 2010 there were 233 (2.87%) articles found to be published and a total number of 252 (3.10%) articles were published in the year 2011. In the year 2012, a total number of 292 (3.60%) articles were found in the database. In 2013 there were a total number of 378 (4.66%) literature found to be published, where a total number of 349 (4.30%) articles was published in the year 2014. A total number of 293 (3.61%) articles was found to be published in the year 2015 and in the following year 2016 a total number of 292 (3.60%) articles were found to be published. In the year 2017, a total number of 336 (4.14%) articles were found to be published and in 2018 a total number of 403 (4.96%) articles were found to be published. 498 (6.14%) articles were found to be published in the year 2019 and a total number of 600 (7.39%) articles were published in the year 2020, where a total of 645 (7.95%) articles was published in the year 2021. In the year 2022 a total number of 666 (8.21%) articles were found to published where in the year 2023 a total number of 677 (8.34%) articles were found where a total number of 730(9.00%) articles were found to be published in the year 2024. From the data we can see that the highest number of articles were found to be published in the year 2024 with a number of 730 (9.00%), followed in the year 2023 where a total of 677 (8.34%) articles were found to be published which is followed by

the year 2022 with 666 (8.21%) articles found. The lowest number of articles was found to be published in the year 2004 with a total number of 75 (0.92%) articles found, followed by the year 2005 with 98 (1.20%) publications and the year 2000 with 114 (1.40%) publications.

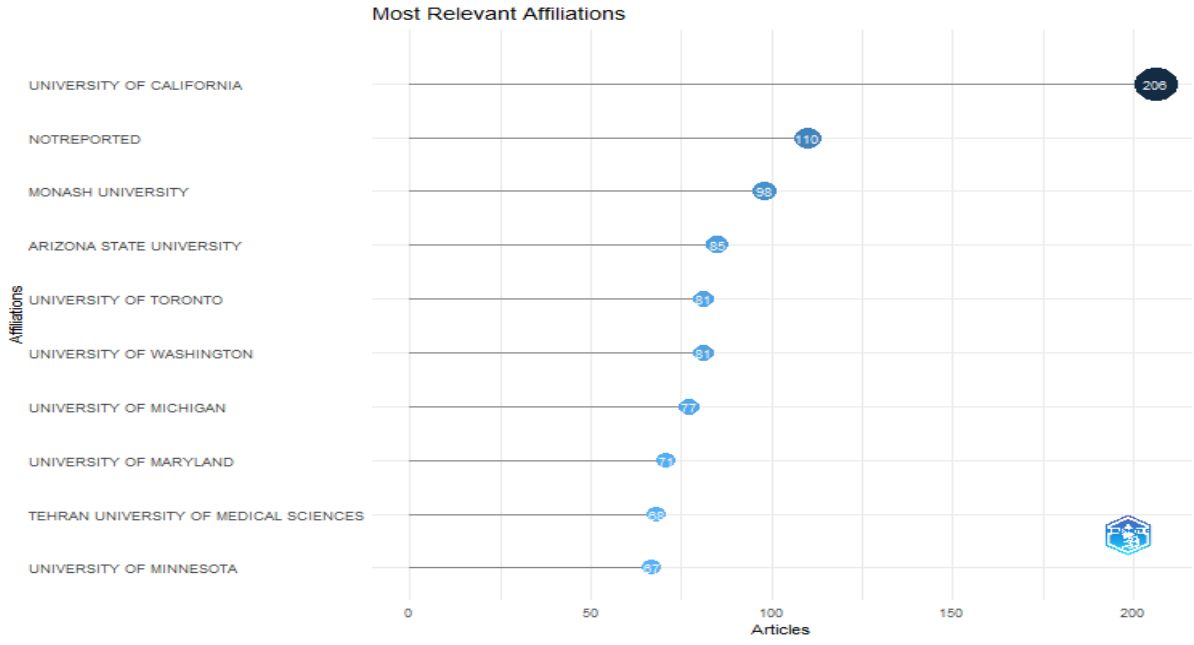
2. Affiliation-wise contribution

The given table and figures show the top 10th affiliation-wise contribution in the database in the field of science process skills research.

Table 2. Top 10th most relevant affiliation-wise contribution

Affiliation	Articles
UNIVERSITY OF CALIFORNIA	206
NOTREPORTED	110
MONASH UNIVERSITY	98
ARIZONA STATE UNIVERSITY	85
UNIVERSITY OF TORONTO	81
UNIVERSITY OF WASHINGTON	81
UNIVERSITY OF MICHIGAN	77
UNIVERSITY OF MARYLAND	71
TEHRAN UNIVERSITY OF MEDICAL SCIENCES	68
UNIVERSITY OF MINNESOTA	67

Figure 2. Top 10th most relevant affiliation-wise contribution



The above Table 2 and Figure 2 show affiliation contribution on literature about science process skills in a selected database and the result shows that university of California have the greatest number of contribution with 206 (2.54%) articles contributed and a total number of 110 (1.35%) articles did not have report name of the affiliation. Monash University has contributed a total number of 98 (1.2%) articles in the database and Arizone State Univerity has a total contribution of 85 (1.04%) articles. A total number of 81 (0.99%) articles were found to be contributed by University of Toranto and University of Washington, while University of Michigan contributed a total number of 77 (0.94%) articles and a total number of 71(0.94%) articles were contributed by University of Maryland. Tehrab University of Medical Sciences contributed a total number of 68 (0.83%) articles and a total number of 67 (0.82%) articles were contributed by University of Minnesota.

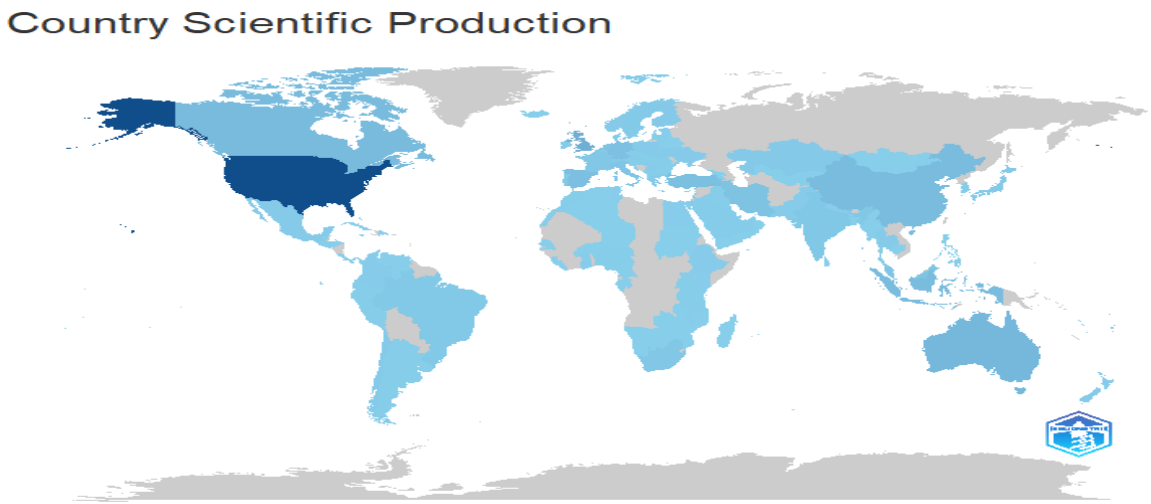
3. Countries-wise frequency of scientific production

The given table and figure below shows top 10th countries wise contribution in field of science process skills research.

Table 3. Top 10th countries-wise scientific production

Region	**Freq**
USA	8331
UK	1904
AUSTRALIA	1333
CANADA	1181
CHINA	1092
INDONESIA	1065
SPAIN	900
TURKEY	847
GERMANY	822
IRAN	658

Figure 3. Top 10th countries-wise frequency scientific production



The above given Table 3 and Figure 3 indicated frequency of countries wise Scientific Production. The given results shows that USA has the most number if contributions with a total number of 8331 articles which is followed by UK with a total number of 1904 articles contribution. The third countries to contribute the most is Australia with a total number of 1333 articles and Canada have contributed a total number of 1181 articles which is followed by China with 1092 articles contributed and Indonesia with 1065 articles contributed. Spain have a total number of 900 articles contributed and Turkey have contributed a total number of 847 articles contributed, Germany with a total number of 822 articles contributed and Iran have a total number of 658 articles contributed.

4. Most globally cited documents

Citations serve as a key indicator of scholarly impact, reflecting both the academic community's engagement with and valuation of particular research contributions. The following analysis presents the ten most globally cited publications in science process skills research.

Table 4. Top 10th most globally cited documents

Paper	Journal	DOI	Total Citations	TC per Year	Normalized TC
TEECE DJ, 2007, STRATEGIC MANAGE J	Strategic Management Journal	10.1002/smj.640	8386	465.8889	92.28509
SPEAR LP, 2000, NEUROSCI BIOBEHAV REV	Neuroscience & Biobehavioral Reviews	10.1016/S0149-7634(00)00014-2	4368	174.72	31.17266
HASSON F, 2000, J ADV NURS	Journal of Advanced Nursing	10.1046/j.1365-2648.2000.t01-1-01567.x	3858	154.32	27.53299
NORRIS FH, 2008, AM J COMMUNITY PSYCHOL	American Journal of Community Psychology	10.1007/s10464-007-9156-6	3340	196.4706	36.10586
VARGO SL, 2008, EUR MANAGE J	European Management Journal	10.1016/j.emj.2008.04.003	2162	127.1765	23.37152
NUTBEAM D, 2008, SOC SCI	Social Science &	10.1016/j.socscimed.2008.09.050	1824	107.2941	19.71769

MED	Medicine				
DWIVEDI YK, 2023, INT J INF MANAGE	International Journal of Information Management	10.1016/j.ijinfomgt.2023.102642	1450	725	267.6984
CHEN C, 2017, J DATA INF SCI	Journal of Data and Information Science	10.1515/jdis-2017-0006	1269	158.625	51.43353
HERTZOG C, 2008, PSYCHOL SCI PUBL INTEREST SUPPL	Psychological Science in the Public Interest	10.1111/j.1539-6053.2009.01034.x	1059	62.29412	11.44794
ASHEIM BT, 2005, RES POLICY	Research Policy	10.1016/j.respol.2005.03.013	1037	51.85	17.67716

Figure 4. Top 10th most globally cited documents

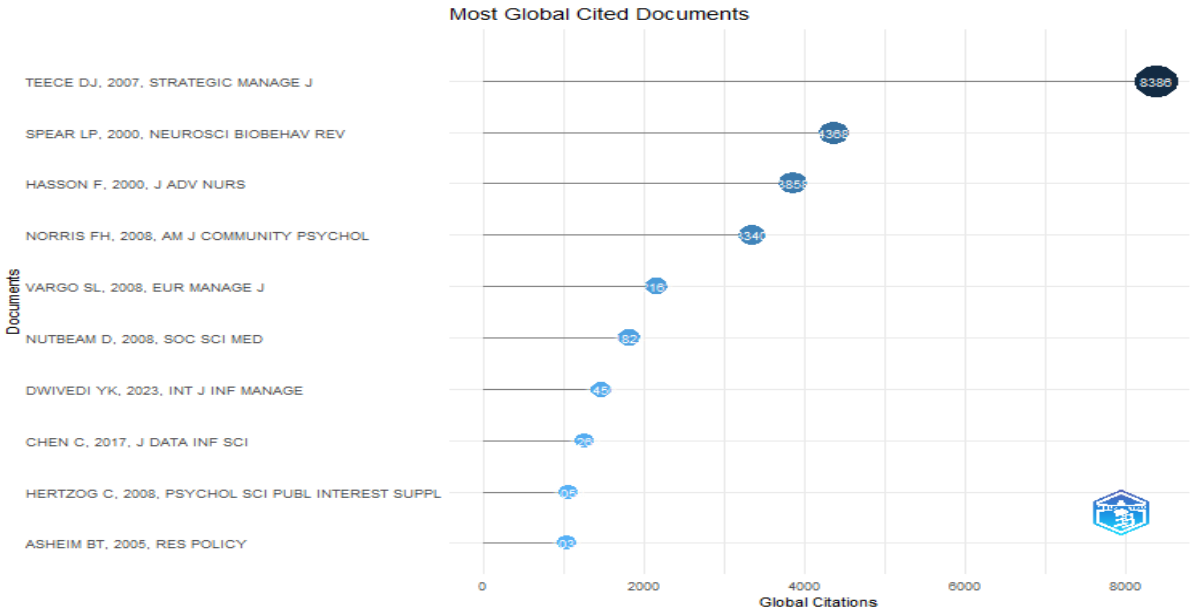


Table 4 and Figure 4 shows information on most globally cited documents and the data shows that David J. Teece articles title Explicating Dynamic Capabilities: The Nature and Microfoundations Of (Sustainable) Enterprise Performance published in Strategic Management Journal have a total number of 8386 citations with 465.8889 citation per year. The second paper to get the highest citation is written by LP Spear with the articles title The Adolescent Brain and Age-Related Behavioral Manifestations in the journal of Neuroscience & Biobehavioral Reviews with a total citation count of 4368 with 174.72 total citations per year. The third paper to get the greatest number of citations is written by Felicity Hasson, Sinead Keeney and Hugh Patrick Mckenna in their paper title Research guidelines for the Delphi Survey Technique published in Journal of Advanced Nursing have a total citation score fo 3858 with a total citation count of 154.32 per year. Fran H. Norris et.al paper title Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness published in American Journal of Community Psychology have a total citation count of 3340 with a total number of 196.4706 total citation per year. An article written by Stephen L. Vargo, Paul P. Maglio and Melissa Archpru Akaka in their paper title On Value and Value Co-Creation: A Service Systems and Service Logic Perspective published in European Management Journal have a total citation score of 2162 with 127.1765 total citation per year. Don Nutbeam paper title The Evolving Concept Of Health Literacy published in Social Science & Medicine have a total citation count of 1824 with 107.2941 total citation per year. Yogesh K. Dwivedi et. al in their paper title Opinion Paper: "So What If Chatgpt Wrote It?" Multidisciplinary Perspectives On Opportunities, Challenges And Implications Of Generative Conversational AI For Research, Practice And Policy published in International Journal of Information Management received a total number of 1450 citations with 725 total citation per year. Chaomei Chen paper title Science Mapping: A Systematic Review of the Literature published in Journal of Data and Information Science have a total number of 1269 citations with 158.625

total citation per year. Christopher Hertzog et al in their paper title Enrichment Effects on Adult Cognitive Development: Can the Functional Capacity of Older Adults Be Preserved and Enhanced? published in Psychological Science in the Public Interest received a total citation count of 1059 with 62.29412 total citation per year and Bjørn T. Asheim and Lars Coenen in their paper titled Knowledge Bases And Regional Innovation Systems: Comparing Nordic Clusters published in Research Policy have a total citation score of 1037 with 51.85 total citation per year.

5. Most frequently used keyword

Keywords serve as valuable indicators of a study's primary focus and thematic content, enabling researchers to identify core concepts and research trends. By analyzing frequently occurring keywords, one can discern the predominant themes and terminologies employed within a particular field of study. The given table and figure below show list of top 10th most frequently used keywords.

Table 5. Top 10th most frequently used keywords

Words	**Occurrences**
Human	2196
Article	1837
Humans	1716
Female	1385
Male	1251
Adult	1000
Education	803
Curriculum	744
Learning	728
Skill	688

Figure 5. Top 10th most frequently used keywords

Table 5 and Figure 5 show the most frequently used keywords. In the collected documents the result shows that the word human is found to be the most frequent keyword used occurring 2196 times, followed by the word article which was found to occur 1837 times and the word humans is found to occurred 1716 times. The word female is found to occur 1385 times followed by the word male occurs 1251 times and the word adult occurs 1000 times. The word education occurred 803 time and the word curriculum was found to occur 744 times which is followed by the word learning with 728 times and the word skill is found to occur 688 times.

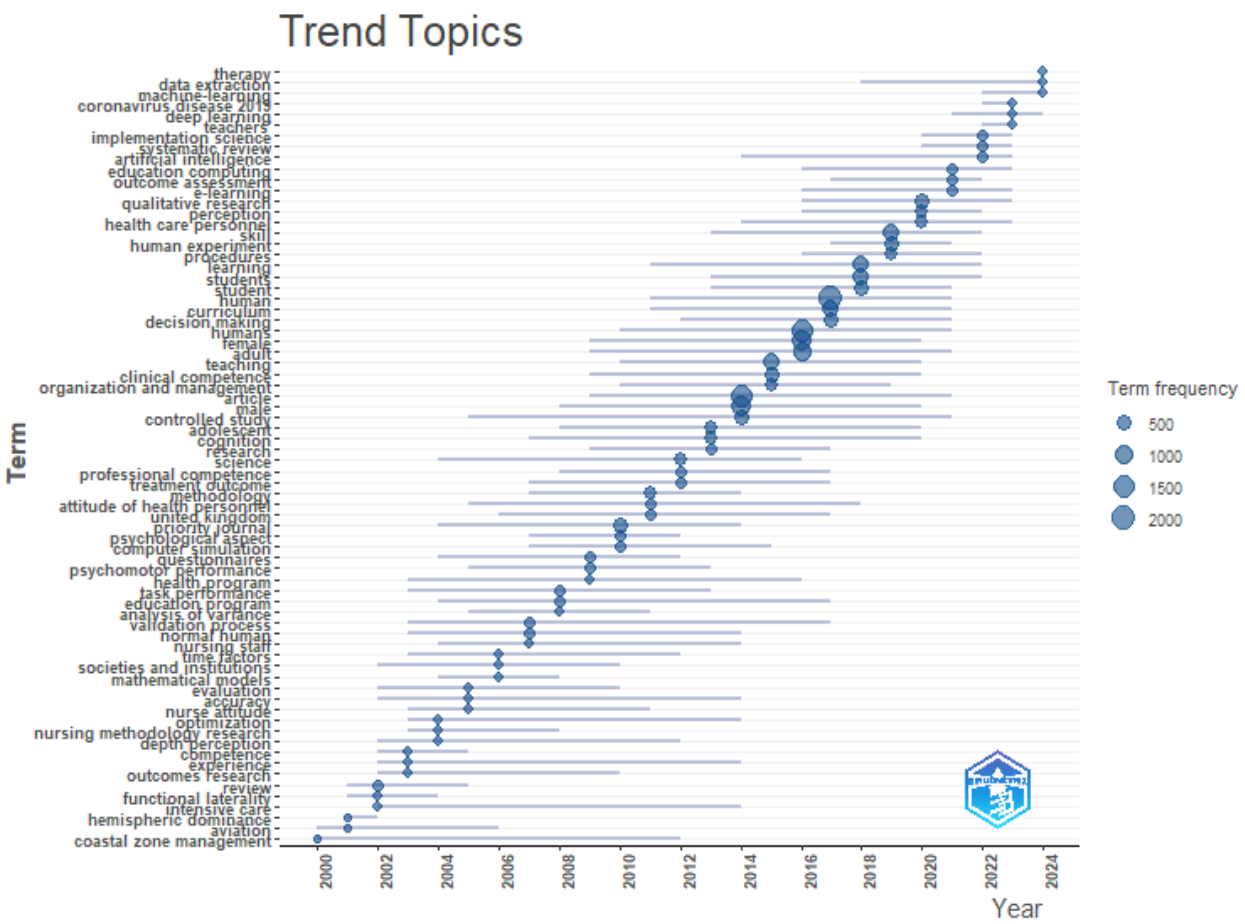
6. Most trending topic in the field of science process skills

Scientometric analysis serves as a robust methodological approach for detecting emerging research trends within specific academic domains. The given table and figure show top 10th most trending topic in the field of science process skills.

Table 6. Top 10th most trending topic in the field of science process skills

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
Therapy	25	2024	2024	2024
data extraction	18	2018	2024	2024
machine-learning	12	2022	2024	2024
deep learning	22	2021	2023	2024
coronavirus disease 2019	41	2022	2023	2023
teachers'	19	2022	2023	2023
implementation science	132	2020	2022	2023
systematic review	118	2020	2022	2023
artificial intelligence	78	2014	2022	2023
education computing	94	2016	2021	2023

Figure 6. Top 10th most trending topic in the field of science process skills



The given Table 6 and Figure 6 show the most trending topic in science process skills research which will be helpful for future research. The data shows that the term therapy is the most trending topic with a term frequency of 25 found mainly in the year 2024. The second trending term is data extraction with 18 frequency and found mainly in the year 2018 and 2024. The third most trending topic is machine-learning with 12 frequency which was found mainly in the year 2022 and 2024. The next term that was found trending is deep learning with 22 frequency which was found to be used in the year 2021,2023 and 2024. The term coronavirus disease 2019 is found 41frequency and this research is found mainly in the year 2022 and 2023, followed by teachers with 19 times frequency and found to becoming in the year 2022 and 2023. The team implementation science term frequency of 132 which was found in the year 2020,2022 and 2023 followed by the term systematic review with 118 frequency mainly found to be trend in the year 2020, 2022 and 2023. The team artificial intelligence is found 78 frequency and trend mainly in the year 2014, 2022 and 2023 and the term education computing with 94 frequency and found in the year 2016, 2021 and 2023. As per the result it shows that therapy, deep-learning, machine learning and deep learning are found to be the most trending topic at present.

7. Country collaboration networks in science process skills studies

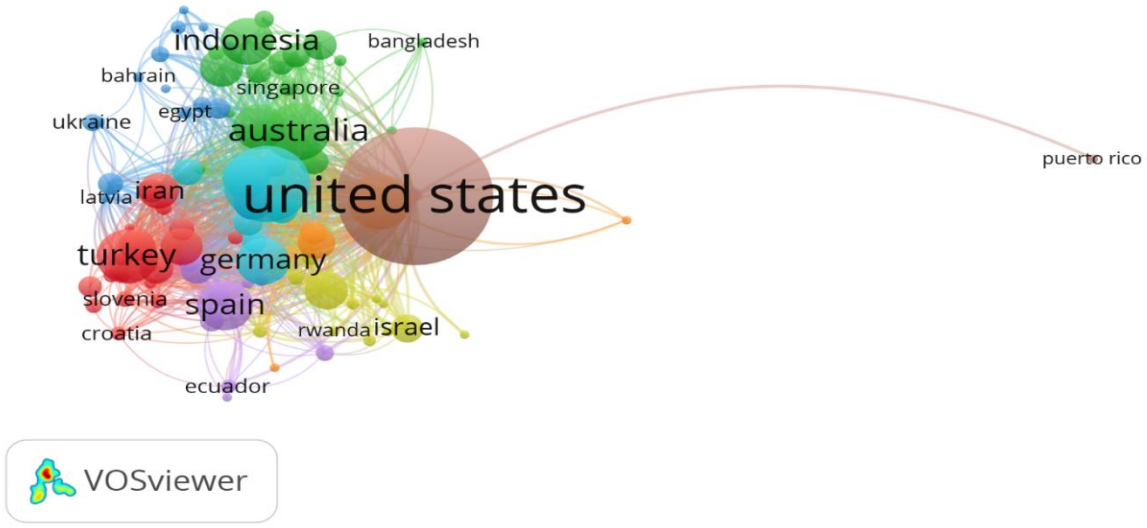
Through network analysis of collaborative publications, researchers can identify key partner countries, measure collaboration strength, and track the evolution of global research partnerships over time. The given table and figure show top 10th leading country collaboration networks in science process skills studies.

Table 7. Top 10th leading country collaboration networks in science process skills studies

From	To	Frequency
USA	CANADA	86

USA	UNITED KINGDOM	75
USA	AUSTRALIA	51
UNITED KINGDOM	AUSTRALIA	50
USA	GERMANY	46
UNITED KINGDOM	GERMANY	42
USA	NETHERLANDS	39
USA	CHINA	36
UNITED KINGDOM	NETHERLANDS	35
UNITED KINGDOM	CANADA	29

Figure 7. Countries collaboration network



The above given Table 7 and Figure 7 show top 10th countries collaboration network, the data shows that USA and Canada have the most number of collaboration with a total frequency of 86 followed by USA and United Kingdom with a total frequency of 75. The third country are USA and Australia with a total collaboration frequency of 51 followed by United

Kingdom and Australia with a total frequency of 50. USA and Germany have a total collaboration of 46 frequency and United Kingdom and Germany have a total collaboration of 42. A total collaboration frequency of 39 is found between USA and Netherlands where USA and China have collaboration frequency of 39. United Kingdom and Netherlands have a total collaboration frequency of 35 and United Kingdom and Canada have a total collaboration frequency of 29. The given result shows that USA has the most number of collaboration work with other countries.

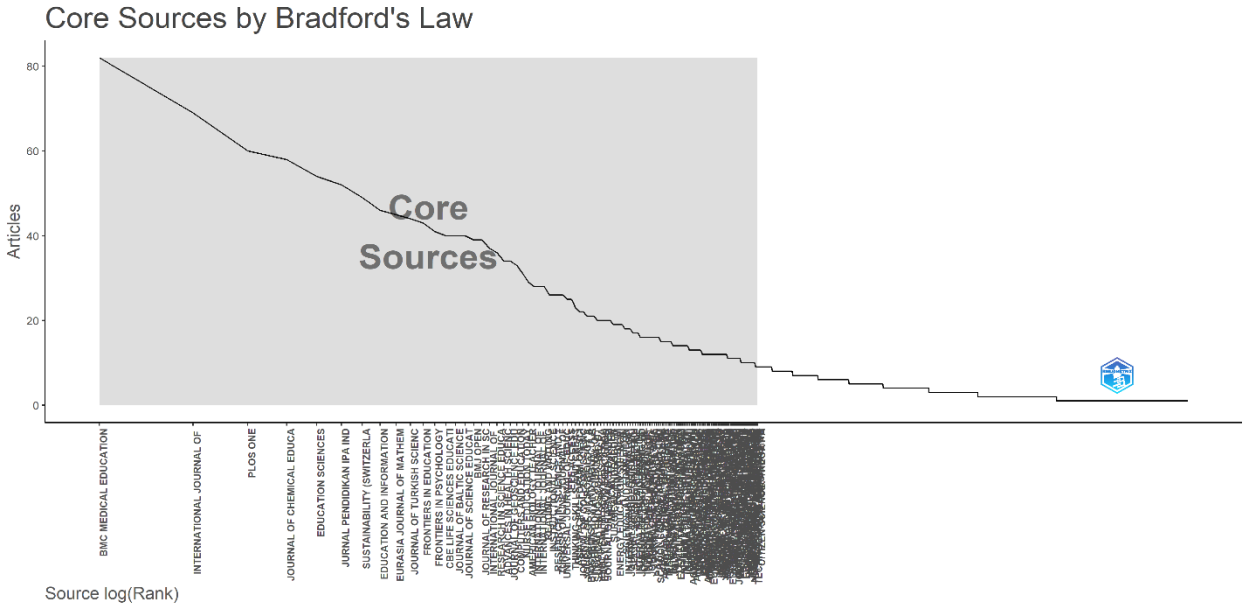
8.Top 10th core source in the field of science process skills research by Bradford's Law.

Bradford's Law of Scattering enables the identification of core sources within the field of science process skills, allowing us to determine the leading journals that contribute most significantly to literature. The results of this analysis are presented in Table 8 and illustrated in Figure 8 below.

Table 8. Top 10th core source in the field of science process skills research by Bradford's Law

SO	Rank	Freq	cumFreq	Zone
BMC MEDICAL EDUCATION	1	82	82	Zone
INTERNATIONAL JOURNAL OF SCIENCE EDUCATION	2	69	151	Zone
PLOS ONE	3	60	211	Zone
JOURNAL OF CHEMICAL EDUCATION	4	58	269	Zone
EDUCATION SCIENCES	5	54	323	Zone
JURNAL PENDIDIKAN IPA INDONESIA	6	52	375	Zone
SUSTAINABILITY (SWITZERLAND)	7	49	424	Zone
EDUCATION AND INFORMATION TECHNOLOGIES	8	46	470	Zone
EURASIA JOURNAL OF MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION	9	45	515	Zone
JOURNAL OF TURKISH SCIENCE EDUCATION	10	44	559	Zone

Figure 8. Core source in the field of science process skills research by Bradford's Law



The above Table and Figure show the core source of science process skills research in the Scopus database. From the data we can find that BMC Medical Education ranks the highest with a frequency of 82, the second highest source is the International Journal of Science Education with a frequency of 69, and the third highest score is PLOS ONE with a total frequency of 60. The fourth highest source is the Journal of Chemical Education, with a total frequency of 58, followed by the source Education Sciences, with a total frequency of 54. The sixth highest found source is Jurnal Pendidikan Ipa Indonesia with a total frequency of 52, and the seventh highest found source is Sustainability (Switzerland) with a total frequency of 49, which is followed by Education and Information Technologies with a total frequency of 46. Eurasia Journal of Mathematics, Science and Technology Education is found in the ninth place

with a total frequency of 45, and in the tenth place, Journal of Turkish Science Education is found with a total frequency of 44.

Discussion

The scientometric analysis from 2000 to 2024 reveals SPS research field that is not only growing but undergoing significant identity transformation. The findings illustrate a tension between the field's educational roots and its new role as a driver of economic innovation, as evidenced by the influence of management theory. The data reveal a community grappling with its boundaries, caught between core educational research and the vast expanse of applied science that utilizes these skills. Most profoundly, the emergence of AI and machine learning as trending topics signals an imminent revolution, challenging us to redefine SPS for an age of human-AI collaboration. The trending topics analysis clearly shows the rapid emergence of "machine learning," "deep learning," and "artificial intelligence." It is the point to a paradigm shift in the very nature of scientific inquiry. The focus is shifting from teaching students to perform all skills independently to teaching them to effectively partner with intelligent tools for data extraction, pattern recognition, and modeling. It signals that the value of SPS is increasingly being framed not just through an educational or democratic lens (fostering scientific literacy for informed citizenship) but through an economic and instrumental lens.

Future research should explore the long-term impacts of SPS on student outcomes, the role of SPS in addressing global challenges like climate change and public health, and strategies for equitable access to SPS training worldwide. Policymakers, educators, and researchers can use these insights to design more effective science curricula, foster international partnerships, and promote innovative teaching methodologies that prepare learners for the complexities of the modern scientific landscape.

Conclusion

This study used data to track research trends in Science Process Skills (SPS). It was found that research in this area is steadily growing, indicating that it's becoming increasingly important in science education. Technological innovations, particularly AI and digital tools, are transforming SPS pedagogy, while strong North American European research networks highlight the field's global scope. The study emphasises the value of evidence-based teaching approaches and identifies crucial areas for future research, including long-term skill development and equitable access to quality science education. For educators and policymakers, these insights provide actionable guidance for enhancing SPS instruction through curriculum innovation, teacher training, and technology integration. The coexistence of enduring themes and emerging topics reflects both stability and dynamism in SPS research. By systematically mapping this evolving landscape, the study advances understanding of SPS as critical components of 21st-century scientific literacy and problem-solving competence, offering a foundation for future research and practice in science education. In conclusion, the SPS field is evolving beyond its traditional pedagogical foundations, shaped by technological disruption, global economic agendas, and a pressing need for more equitable and relevant research frameworks.

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