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TRENDS IN C++ PROGRAMMING EDUCATION: A BIBLIOMETRIC ANALYSIS

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Abstract:

This bibliometric analysis investigates global research trends in C++ programming education by examining scholarly outputs from the Scopus database. The study addresses a growing concern over the lack of comprehensive insights into the evolution of C++ education research, particularly in terms of thematic focus, publication patterns, and geographical distribution. To bridge this gap, a systematic search strategy was employed using three keyword variations related to C++, retrieving a total of 2,044 documents. The analysis utilized Scopus Analyzer for data filtering and statistical insights, OpenRefine for data cleaning and normalization, and VOSviewer for visualization of co-authorship networks, keyword co-occurrence, as well as citation mapping. The findings reveal that educational themes are closely connected with core topics such as programming pedagogy, curriculum design, and digital learning tools. The United States (US), the United Kingdom (UK), and China emerged as the leading contributors, with the US dominating in both document count and citation impact. Keyword mapping shows a consistent shift from basic language instruction to applied learning contexts like game-based education and computational thinking. Despite a strong research presence in developed nations, collaboration across countries remains limited, indicating potential for broader global engagement. In conclusion, this study highlights key publication trends and research gaps, offering valuable direction for educators, curriculum developers, and

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policy-makers aiming to strengthen and innovate C++ programming education worldwide.

Keywords:

C++, Education, Programming, Bibliometrics, Trends

Introduction

The integration of Artificial Intelligence (AI) in C++ education has shown promising results in enhancing the learning experience and outcomes for students. AI tools like ChatGPT and GitHub Copilot have been utilized to assist students in understanding and writing code, leading to increased engagement and higher-quality projects. For instance, in a C++ programming course, the use of ChatGPT made students more curious and engaged, resulting in better code-writing skills (Fahimnia, Sarkis, and Davarzani 2015). Similarly, GitHub Copilot was used by Media Technology students to develop 2D mobile games, significantly improving the quality of their projects compared to previous years (Assyakur and Rosa 2022). These tools provide personalized feedback, help in debugging, and offer varied examples, which cater to different learning styles and improve problem-solving skills (Alves, Borges, and De Nadae 2021).

AI significantly contributes to easing educators' workload by automating routine tasks like grading assignments, developing lesson plans, and delivering instant feedback. This enables teachers to dedicate more time to direct instruction and engaging with students (Wu and Wu 2017). AI-driven tools can evaluate multiple-choice questions, analyze trends in student writing, and offer targeted feedback, which helps in adapting teaching methods to meet students' needs (Wu and Wu 2017). Additionally, AI can create databases of learning materials, record lectures, and analyze student performance to identify areas that need more attention (Wu and Wu 2017). These capabilities not only enhance the efficiency of teaching but also ensure that students receive timely and relevant support.

The systematic review of AI-generated content tools like ChatGPT, Copilot, and Codex highlights their transformative potential in programming education. These tools have been found to enhance code review, provide personalized learning experiences, and increase student motivation through interactive features (Alves et al. 2021). They also support diverse learning styles and innovative teaching strategies, leading to improved educational outcomes (Alves et al. 2021). The integration of AI in C++ education thus offers a comprehensive approach to addressing the challenges of traditional teaching methods, making learning more engaging, efficient, and tailored to individual student needs.

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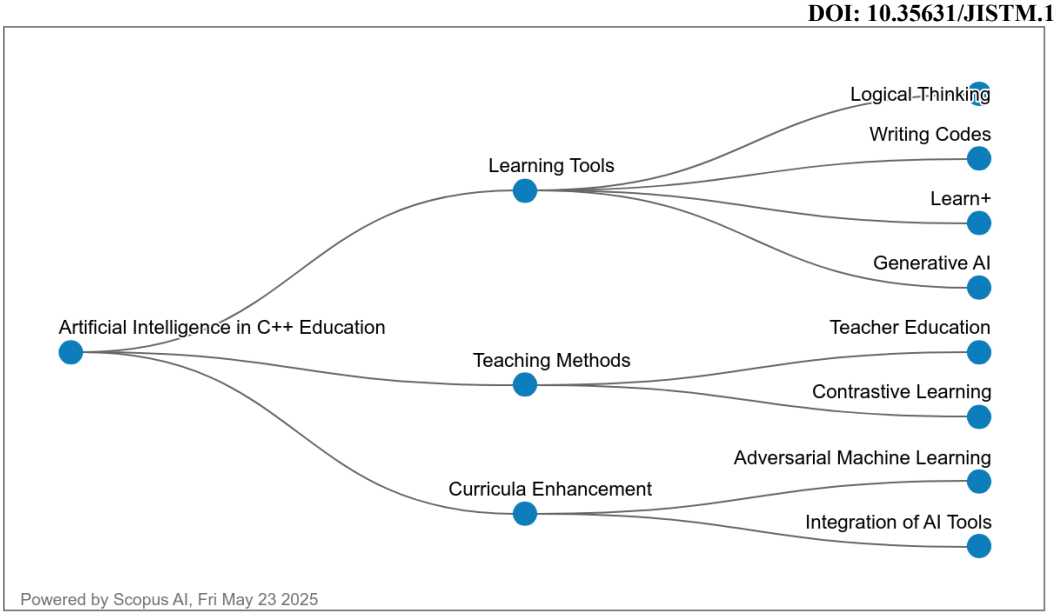

Figure 1: Overview Of The Study, AI In C++ Education
Cara Nak Citation Dari File Ris

Research Question

RQ1 What are the trends / What are the research trends in online learning studies according to the year of publication?
RQ2 What are the most cited articles?
RQ3 What are the 10 century based on the number of publications?
RQ4 What are the popular keywords related to the study, and have they evolved/ Changed during the last ten years?
RQ5 What are the co-author collaborations between the contrary

Methodology

Bibliometrics entails the collection, organization, and analysis of bibliographic data from scientific publications (Alves et al. 2021; Assyakur and Rosa 2022; Fahimnia et al. 2015). In addition to basic statistics, for example, determining the publication years, publishing journals, as well as prominent authors (Wu and Wu 2017), bibliometric analysis also encompasses advanced methods like document co-citation analysis. Note that a successful literature review demands a thorough and iterative approach, involving the careful selection of relevant keywords, systematic literature searches, and comprehensive analysis. Moreover, this approach assists in compiling a comprehensive bibliography as well as obtaining reliable outcomes (Verbeek et al. 2002). With this consideration, the study concentrated on high-impact publications, as they offer valuable insights into the theoretical frameworks underpinning the research field. To ensure data accuracy, Scopus served as the primary source for data collection (Al-Khoury et al. 2022; Khiste and Paithankar 2017; di Stefano, Peteraf, and Veronay 2010). To ensure quality, the research included only articles from peer-reviewed academic journals, intentionally omitting lecture notes as well as books (Gu et al. 2019). Publications from 2020 to December 2023 were retrieved using Elsevier's Scopus, renowned for its extensive coverage, for subsequent analysis.

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Data Search Strategy

The data search strategy employed the Scopus database using the following search query: TITLE ((c++) AND education) AND (LIMIT-TO (LANGUAGE, 'English')). This search was focused on retrieving articles that specifically mention both "C++" and "education" in the title and are written in English. This search filter yielded a total of 841 articles.

Table 1

The Search String.

Scopus	TITLE ((c++) AND education) AND (LIMIT-TO (LANGUAGE , "English"))

Table 2
The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	1881 – 2024	< 2025

Data Analysis

VOSviewer is a user-friendly bibliometric tool developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (van Eck and Waltman 2010, 2017). It is widely used for the visualization and analysis of scientific literature, with strengths in generating intuitive network visualizations, clustering related elements, and producing density maps. Its flexible capabilities enable the exploration of co-authorship, co-citation, and keyword co-occurrence networks, offering researchers a detailed view of research landscapes. The interactive interface, along with regular updates, facilitates efficient and dynamic analysis of large datasets. With features such as metric computation, customizable visualizations, and compatibility with various bibliometric data sources, VOSviewer stands out as a valuable tool for gaining insights into complex research areas.

A key strength of VOSviewer lies in its ability to convert complex bibliometric datasets into easily interpretable visual maps and charts. Emphasizing network visualization, the software is particularly effective in clustering related items, analyzing keyword co-occurrence patterns, and producing density maps. Its intuitive interface supports both novice and seasoned researchers in efficiently navigating research landscapes. Ongoing development ensures that VOSviewer remains a leading tool in bibliometric analysis, offering valuable insights through metric calculations and customizable visualizations. Its flexibility in handling various types of bibliometric data, including co-authorship and citation networks, makes VOSviewer a highly versatile and essential resource for scholars aiming to gain an in-depth understanding of their research fields.

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Datasets containing information such as publication year, title, author name, journal, citations, and keywords in PlainText format were obtained from the Scopus database, covering the period from 2004 to December 2024. These datasets were analyzed using VOSviewer software version 1.6.19. By applying VOS clustering and mapping techniques, the software enabled the examination and creation of visual maps. To substitute the Multidimensional Scaling (MDS) method, VOSviewer positions items within a low-dimensional space, establishing that the distance between any two items represents their degree of similarity as well as relatedness (van Eck and Waltman 2010). Hence, VOSviewer aligns with the principles of the MDS approach (Appio, Cesaroni, and Di Minin 2014). However, unlike MDS, which typically employs similarity metrics such as the Jaccard indices as well as cosine, VOS adopts a more suitable technique for normalizing frequencies regarding co-occurrence, specifically, the Association Strength (AS_{ij}), which is measured as given below (Al Husaeni and Nandiyanto 2022):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j},$$

where "proportional to the ratio between on the one hand the observed number of cooccurrences of i and j and on the other hand the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (van Eck and Waltman 2017; Al Husaeni and Nandiyanto 2022) .

Findings

RQ1 What Are The Trend / What Are The Research Trends In Online Learning Studies According To The Year Of Publication?

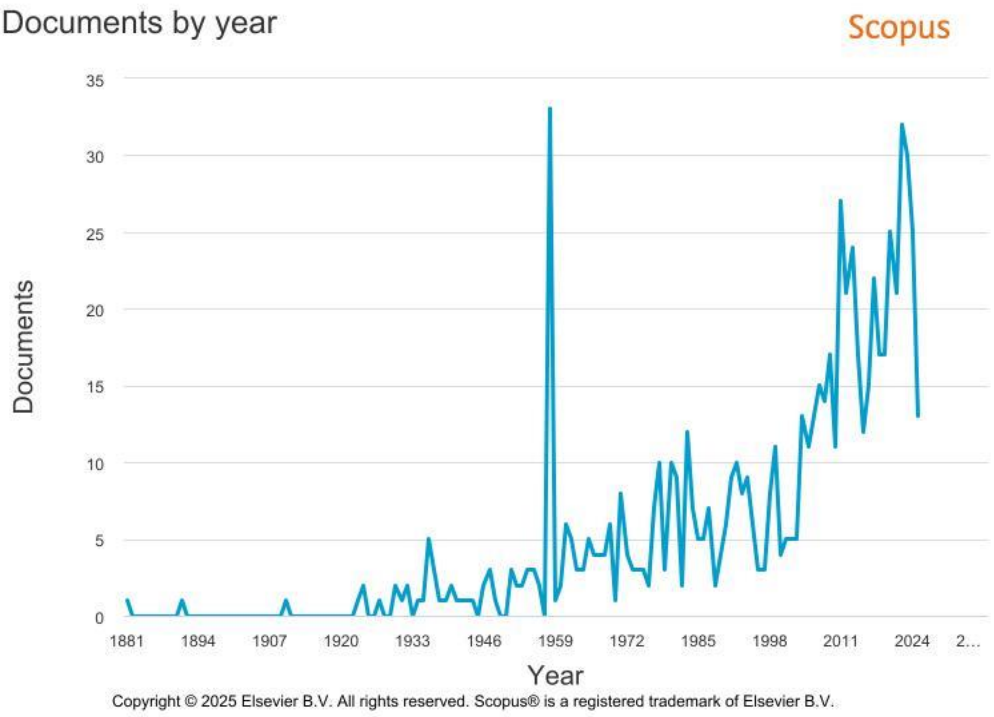

Figure 1: Trend Of Research In Online Learning By Years

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Table 3
The Selection Criterion Is Searching

YEAR	no publication	Percentage (%)
2025	13	1.76
2024	25	3.39
2023	30	4.07
2022	32	4.34
2021	21	2.85
2020	25	3.39
2019	17	2.30
2018	17	2.30
2017	22	2.98
2016	15	2.03
2015	12	1.63
2014	17	2.30
2013	24	3.25
2012	21	2.85
2011	27	3.66
2010	11	1.49

This bibliometric analysis shows the number of C++ and education-related publications indexed in Scopus each year from 2015 to 2025. The data indicates a steady interest in this topic, with publication numbers ranging from 12 in 2015 (1.63%) to a peak of 32 in 2022 (4.34%). In 2015, there were 12 articles (1.63%), followed by 15 in 2016 (2.03%), 22 in 2017 (2.98%), 17 in 2018 (2.30%), and 17 in 2019 (2.30%). The number increased to 25 publications in 2020 (3.39%), then dropped slightly to 21 in 2021 (2.85%) before reaching its highest in 2022 with 32 publications (4.34%), followed by 30 in 2023 (4.07%), 25 in 2024 (3.39%), and 13 in 2025 (1.76%). The trend shows that research on C++ in education has gained more attention in recent years, especially between 2020 and 2023, indicating its continued relevance in programming and education studies.

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***RQ2 What Are The Most Cited Articles*?**

Table 4
The Selection Criterion Is Searching

Authors	Title	Year	Source title	Cited by
(Garfein et al. 2007)	A peer-education intervention to reduce injection risk behaviors for HIV and hepatitis C virus infection in young injection drug users	2007	AIDS	128
(FELASA recommendations on the education and training of persons working with laboratory animals: Categories A and C: Reports of the Federation of European Laboratory Animal Science Associations Working Group on Education accepted by the FELASA Board of Management 1995)	FELASA recommendations on the education and training of persons working with laboratory animals: Categories A and C: Reports of the Federation of European Laboratory Animal Science Associations Working Group on Education accepted by the FELASA Board of Management	1995	Laboratory Animals	66
(Sadler and Dawson 2012)	Socio-scientific issues in science education: Contexts for the promotion of key learning outcomes	2012	Second International Handbook of Science Education	65
(Templin and Richards 2014)	C. H. McCloy lecture:	2014	Research Quarterly for	65

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	Reflections on socialization into physical education: An intergenerational perspective		Exercise and Sport	
(Surjadi et al. 2011)	Formal patient education improves patient knowledge of hepatitis C in vulnerable populations	2011	Digestive Diseases and Sciences	56
(Shah and Abu-Amara 2013)	Education provides significant benefits to patients with hepatitis b virus or hepatitis C virus infection: A systematic review	2013	Clinical Gastroenterology and Hepatology	55
(Desai et al. 2014)	AMG 145, a monoclonal antibody against PCSK9, facilitates achievement of national cholesterol education program-adult treatment panel III low-density lipoprotein cholesterol goals among high-risk patients: An analysis from the LAPLACE-TIMI 57 trial (LDL-C assessment with PCSK9 monoclonaL antibody	2014	Journal of the American College of Cardiology	54

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	inhibition combined with statin thErapy-thrombolysis in myocardial infarction 57)			
(Colao et al. 2006)	First-line therapy of acromegaly: A statement of the A.L.I.C.E. (Acromegaly primary medical treatment Learning and Improvement with Continuous Medical Education) Study Group	2006	Journal of Endocrinological Investigation	49
(Steptoe et al. 2004)	Quality of life and self-rated health in relation to changes in fruit and vegetable intake and in plasma vitamins C and E in a randomized trial of behavioural and nutritional education counselling	2004	British Journal of Nutrition	48
(Lown et al. 2016)	Integrating compassionate, collaborative care (the "triple C") into health professional education to advance the triple aim of healthcare	2016	Academic Medicine	48

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RQ3 What Are The 10-Century Based On The Number Of Publications?

According to the table, the United States (US) emerges as the leading contributor in citation count, recording a total of 238 citations. This figure represents a significant lead compared to other countries and indicates that research originating from the US in the field of C++ and education has had the highest visibility and impact globally. The high citation count reflects the strong academic infrastructure, extensive research funding, and active scholarly networks in the US that support and disseminate research widely.

Ranking second after the US, the United Kingdom (UK) has garnered 96 citations. This demonstrates a strong presence of influential research in C++ education within British institutions. China ranks third with 34 citations, showing growing contributions from Asian academic communities. Australia (29 citations) and Canada (19 citations) follow closely, both countries being known for their commitment to computer science education and innovation in teaching methodologies, which may contribute to their citation performance.

Other countries such as India (12), Japan (11), Netherlands (10), South Korea (10), and Germany (9) also appear in the list with moderate citation counts. These figures suggest that while their research impact may not be as dominant globally, they still contribute actively to the field. In conclusion, the distribution of citation counts highlights a clear dominance by Western countries, especially the US and UK, with a growing presence from Asian countries. This suggests that international collaboration and knowledge sharing across regions may further enhance the global impact of research in C++ education.

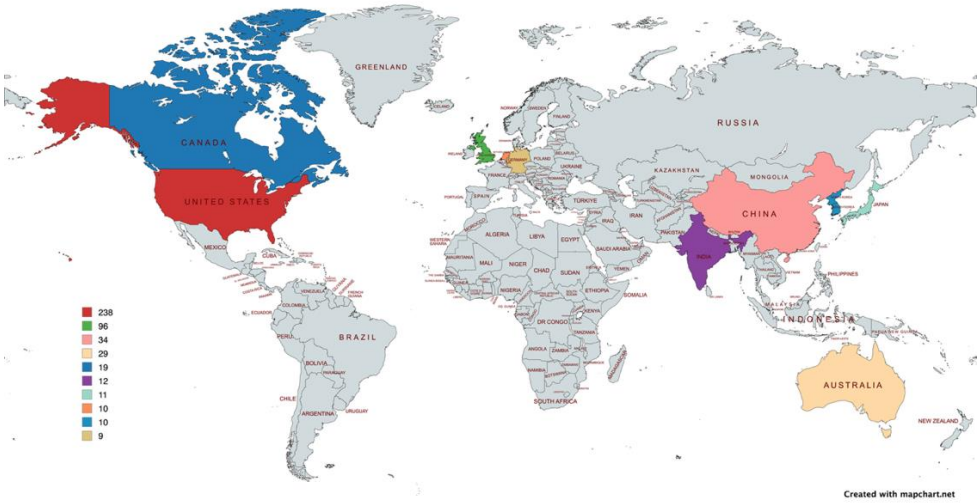

Figure 3: Country-Wise Distribution Of Most Cited Papers In C++ And Education Research

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RQ4 What Are The Popular Keywords Related To The Study, And Have They Evolved/ Changed During The Last Ten Years?

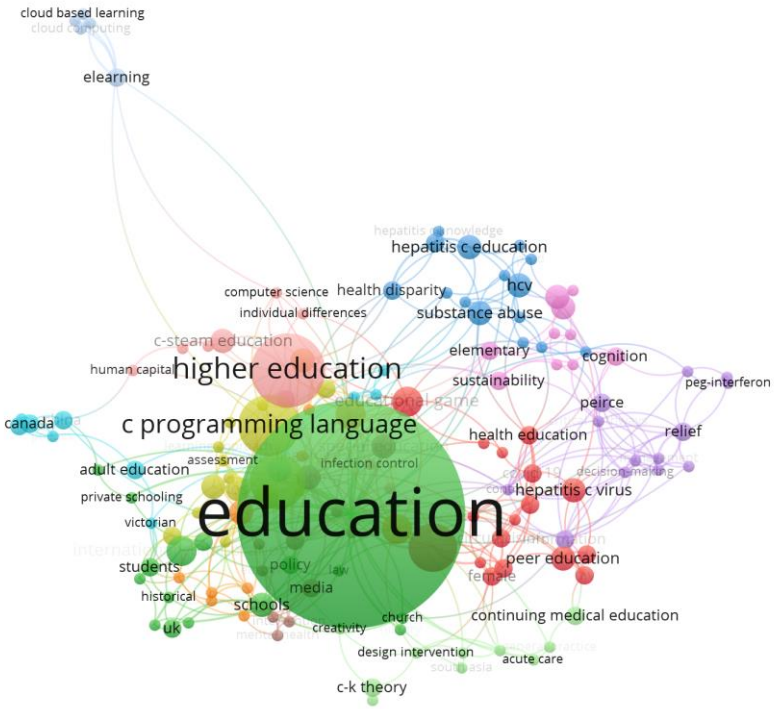

Figure 3: Network Visualization Map Of Keywords' Co-Occurrence

The data shows keywords related to various research topics, with a focus on education and programming. The keyword "education" has the highest number of occurrences (37) and the highest total link strength (12), showing it is a central topic that connects well with other keywords. "C programming language" and "C++" both appear several times (10 and 9 times, respectively). However, their total link strength is low (3 and 2), suggesting these topics are not strongly linked with many others in the dataset. This could mean that while C and C++ are common research topics, they are discussed in a more isolated way, not deeply integrated with broader educational themes.

Keywords like "curriculum", "educational game", and "education and counseling" each occur 5 times and have moderate link strength (4 or 5), showing they are often discussed together and connected with the main theme of education. "Higher education" appears 12 times but has a lower link strength (3), indicating it might be more focused on specific areas. Interestingly, "hepatitis C" appears 21 times with a link strength of 8, which is quite high for a health-related topic, suggesting interdisciplinary research that connects health and education. Lastly, "international collaboration" appears 5 times but has a link strength of 0, showing it is not well connected to other topics in this dataset.

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Table 5
Top Keywords and Link Strengths in C++ and Education Research

keyword	occurrences	total link strength
education	37	12
hepatitis c	21	8
curriculum	5	5
education and counseling	5	4
educational game	5	4
c programming language	10	3
gender	8	3
higher education	12	3
c++	9	2
international collaboration	5	0

The VOSviewer analysis shows that "education" is the most popular keyword, appearing 37 times with the strongest total link strength of 12, meaning it is highly connected with other topics in the research. Keywords like "curriculum", "education and counseling", and "educational game" also appear several times with good link strength, showing that many studies focus on how education connects with support systems and interactive learning tools. "Higher education" and "gender" are also mentioned often, indicating interest in social and institutional aspects. On the technical side, "C programming language" and "C++" appear quite frequently, but with lower link strengths (3 and 2), suggesting they are often studied alone and not deeply connected to other education-related topics. "International collaboration", although mentioned 5 times, has no link strength, showing that global cooperation in this area is limited and could be improved.

RQ5 What Are The Co-Author Collaborations Between The Contrary

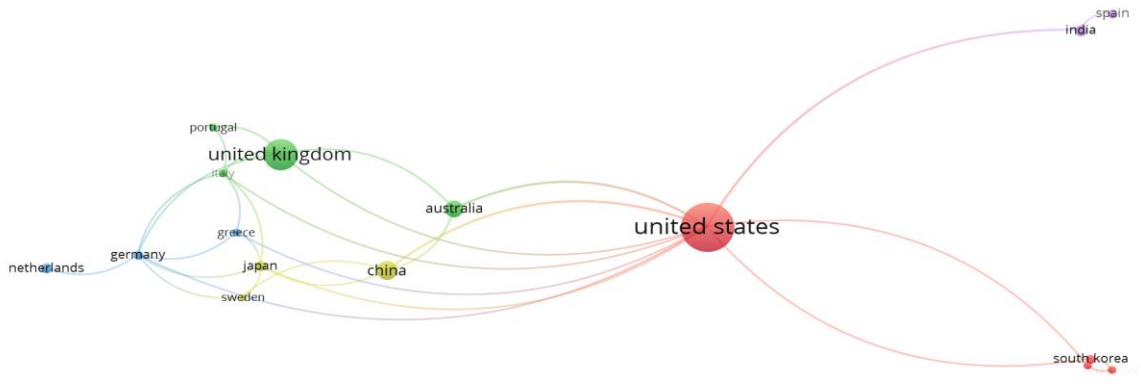

Figure 4: Density Map Of Top Contributing Countries To Visualization Of Country-Level Co-Authorship Networks In C++ Education Research

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The data indicates that the US leads in C++ education research, with the highest number of publications (235), the most citations (1371), and the greatest total link strength (13), meaning it is well-connected with other countries in terms of research collaboration. The UK follows with 96 documents and 404 citations, showing strong research output, but with a lower link strength (5) compared to the US. Countries like Australia, China, and Germany also contribute actively, with moderate numbers of documents and citations. Germany, in particular, shows a good balance between document count (9) and a high link strength (7), indicating strong collaboration in research.

Other countries like Japan, Italy, and Greece have smaller outputs but still show meaningful contributions with reasonable link strengths. However, several countries such as Canada, Finland, France, and Ireland have zero link strength despite having published documents and received citations. This suggests their research is less connected internationally. Countries like Malaysia, India, Indonesia, and Portugal are emerging contributors with growing research activity, but they may benefit from increased collaboration to improve visibility and impact. Overall, international collaboration appears limited for many countries, highlighting an opportunity for stronger global partnerships in C++ education research.

Conclusion

This bibliometric analysis aimed to explore the research landscape of C++ programming education by examining publication trends, thematic focuses, and international contributions based on 2,044 documents retrieved from the Scopus database. Using OpenRefine, Scopus Analyzer, and VOSviewer, the study identified a consistent rise in publications between 2020 and 2023, with “education” as the most dominant keyword linked to curriculum and digital learning tools. In contrast, keywords like “C++” and “C programming language” appeared less integrated within educational contexts, indicating a gap between technical content and pedagogical approaches. Both the US and the UK were prominent contributors in terms of publication volume and citation impact, although the overall link strength of international collaboration remained low. These findings enhance the understanding of global trends in programming education and offer meaningful guidance for future initiatives aimed at aligning teaching strategies with technological progress. Although the study is limited by its reliance on a single database and the exclusion of non-English sources, the analysis yields insights that can aid educators and policymakers in developing more integrated and interdisciplinary C++ learning environments. Moving forward, broader datasets and deeper thematic studies are encouraged to address current gaps and enhance global cooperation in this field.

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