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*Research Article*

# Fostering an Innovation Culture in the Education Sector: A Scoping Review and Bibliometric Analysis of Hackathon Research

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**Abstract:**

Despite originating in the tech industry, hackathons have now been adopted in a variety of domains. However, little is known about the status of hackathon literature within educational research. As the number of studies grows, it is essential to develop an understanding of the current state and identify prevalent topics and trends shaping the literature. Toward this goal, this study conducted a bibliometric analysis and scoping review on hackathon research in the field of education. A total of 249 documents written by 1,309 authors and published in 180 unique sources for the period 2014-2022 were identified. Collectively, the dataset amassed 1,312 citations with an average of 6.69 citations per document. The most prevalent subject areas were computer science, social sciences, engineering, medicine, and business. Word frequency analysis showed that "innovation" was the most occurring word, which represents the fundamental objective of hackathon events. The most influential work was the analysis of hackathons as an informal learning platform. Engineering education was the most trending topic while healthcare is an emerging research cluster. Overall, this study provides a better understanding of the hackathon literature and its research landscape in an educational setting.

**Keywords:**

Hackathon, Innovation, Education, Experiential Learning, Scoping Review, Bibliometric Analysis, R Programming

# INTRODUCTION

In recent years, there has been an intensified interest in social coding events like hackathons (also known as a codefest) among practitioners and researchers (Gama et al., 2022; Goudswaard et al., 2022; Happonen et al., 2021). This trend marks the growing promotion of innovative higher education strategies that engage students in alternative experiential learning opportunities. From the theoretical perspective of experiential learning (Morris, 2020), students must be involved, engaged, and active in the learning process (Garcia, 2023). They are physically placed in rich learning environments where interactions and collaborations with other learners are key. The experiences they acquired by engaging physically, intellectually, and socially are the embodied nature of experiential learning (Jordan et al., 2018). According to Blair (2016), these experiences are also tightly bounded by place and time, making it a located and timed activity. Pedagogically, hackathons (abbreviation of hack and marathon) can stimulate experiential learning by offering students a real-world experience of problem-solving and collaboration through localized and time-constrained events (Avila-Merino, 2019; Pakpour et al., 2022). The potential of hackathons as a tool for experiential learning posits the relevancy of a deeper investigation into the integration of these innovation contests in the field of education.

Although there is no general definition for hackathons, there is a wide agreement that these events bring together groups of individuals (e.g., domain experts, developers, and designers) to create a working product (e.g., software). For example, Garcia (2022) defined hackathons as "*intensive, time-bound events where participants in multidisciplinary teams collaborate and develop innovative solutions to real-world problems*". The origin of hackathons may be from the technology sector but they are also now being conducted in education (Affia et al., 2022; Pakpour et al., 2022; Steglich et al., 2021), business (Flores et al., 2020; Leemet et al., 2021; Valença et al., 2020), health (Ulitin et al., 2022), and other disciplines (Crook et al., 2022; Johnson & Robinson, 2014). This expansion recruited a wide range of professionals and talents, bringing domain experts into project teams. Hackathons and other similar innovation contests have been adopted by these domains to create opportunities for digital transformation and self-disruption (Contreras-Espinosa & Eguia-Gomez, 2022; Franco et al., 2022; Revano & Garcia, 2020; Snow et al., 2019). An extensive review of 381 publications in a span of a decade discovered that hackathon events are catalysts that structure processes, enable participation, and facilitate learning (Olesen & Halskov, 2020). Since this review was contextualized in a research context, hackathon implementation in education has been assessed only to a very limited extent.

As a form of participatory activity, hackathons can be used as a pedagogical procedure to develop skills and competencies that prepare students for the workplace. This methodology is comparable to other time-bounded collaborative events and activities where students learn together in small groups through hands-on experiences (Filippova et al., 2017; Garcia et al., 2022; Kvamsås et al., 2021; Meriläinen et al., 2020). According to Garcia (2022), a growing number of studies in hackathon research indicate that this borrowed pedagogy is starting to take its place in the educational landscape. However, little is still known about the current state of research on hackathons used in an educational setting. The present study fills this knowledge gap by conducting a scoping review and bibliometric analysis to map the literature on hackathon research in the field of education. Blass and Hayward (2014) asserted that schools need to embrace an approach that constitutes innovation in learning ecology. Serdyukov (2017) added that schools should continuously evolve by empowering stakeholders (researchers, teachers, and policymakers) to innovate the theory and practice of teaching and learning. As an emergent area of research, understanding the current state of educational hackathons and discovering prevalent trends is necessary to inform future research. This study will provide the latest insights and perspectives for future hackathon research by answering the following research questions (RQ):

RQ1. What is the general state of hackathon research in the field of education?
RQ2. Who are the most productive authors, countries, and institutions in this field?
RQ3. What are the most relevant hackathon publications in terms of citations?
RQ4. What academic disciplines are used to study educational hackathons?
RQ5. What are the conceptual structure and the trending topics in this domain?

## LITERATURE REVIEW

*The Emergence of Knowledge-Intensive Economies*

As the world becomes more and more globalized, the shift from traditional manufacturing-based to knowledge-intensive economies is becoming more indispensable (Aparicio et al., 2021; Choi et al., 2020; Mohaghegh, 2016). First emerged toward the end of the 1990s, the knowledge-intensive economy refers to an economic system where the production, distribution, and use of knowledge and information is the key driver of economic growth and development (Rezny et al., 2019). Industries such as education, technology, healthcare, finance, and professional services are classified as knowledge-intensive, as the generation, management, and sharing of knowledge and information are the major contributors to value in these industries. The global interest in the transition to a knowledge economy positions knowledge as a driving force of cultural, economic, and social development (Asongu & Andrés, 2020; Jawhar et al., 2022; Zeb, 2022). In the Knowledge-Based View framework, knowledge is regarded as a real strategic resource because it is difficult to imitate. Thus, education is a key component of this emerging type of economy as it develops a skilled workforce, promotes lifelong learning, and fosters innovation.

*Fostering an Innovation Culture in Education*

Innovation is one of the fundamental pillars of a knowledge economy that drives socioeconomic and societal growth in the developed world (Chen et al., 2018; Edwards-Schachter, 2018; Terstriep & Rehfeld, 2020; Zeb, 2022). In common parlance, innovation is an instrument of positive change that introduces new and better ideas, methods, or devices. When successfully implemented and sustained, the merchandise of innovation stimulates global progress by enabling people to have greater access to better infrastructures, resources, and technologies (Espasandín-Bustelo et al., 2023; Santamaría et al., 2021; Zhang et al., 2022). Consistent production of innovative solutions is consequently warranted to advance humanity and our global community. To build innovations, we need innovators and education can play a passive or active role in transforming students into creative and innovative thinkers (Revano & Garcia, 2020). According to Fuad et al. (2020), achieving this principle demands the establishment of innovation cultures (i.e., environments that support creative and innovative ideas) within education settings. This notion corresponds to the findings of Roffeei et al. (2018) stating that the characteristics of an educational institution influence how students interact with the culture of innovation.

### *Hackathons as a Strategy for Educational Innovations*

Establishing an innovation culture in educational institutions necessitates a school climate that encourages experimentation, collaboration, and the use of technology (Altaf et al., 2019; Garcia & Yousef, 2022; Lee & Hung, 2016). Fuad et al. (2020) added that participation in teaching methods that appoint students as developers of innovation projects is necessary to meet these demands. All these pedagogical requirements point to the viability of hackathons as a strategy for strengthening educational innovations. As a platform that connects classroom learnings to real-life scenarios, Garcia (2022) emphasized that hackathons fulfill the needs of students, capstone projects, and society by promoting hard and soft skills, fostering collaborative work, and solving real problems, respectively. Additionally, students concur that hackathons are more authentic than university classes in emulating real-life workplaces and challenges. In their book, Kohne and Wehmeier (2020) described that the general procedure of conducting hackathon events involves three phases: (1) preparation where a detailed plan of the actual hackathon is drawn up, (2) operation which signifies the actual event, and (3) follow-up which transfers valid ideas to actual product development. All three phases are accompanied by continuous communication and documentation. This hackathon procedure is presented in Figure 1.

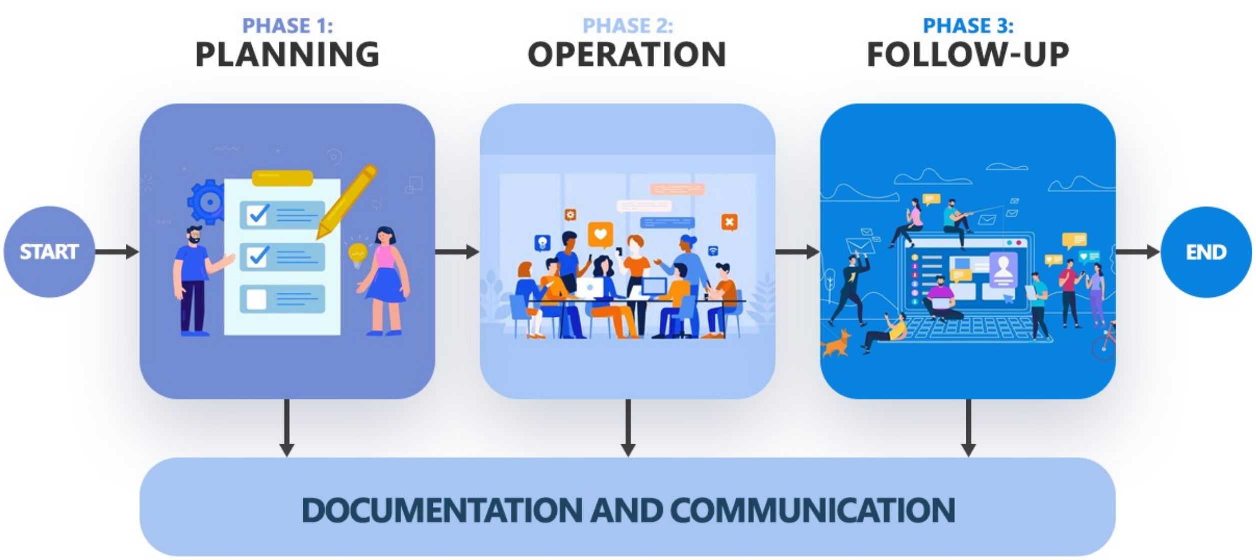


**Figure 1. General Procedure of a Hackathon Event adapted from Kohne and Wehmeier (2020).**


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## MATERIALS AND METHODS

*Research Design*

This study combines scoping review and bibliometric analysis to map and analyze the literature on hackathon implementation in the field of education. A scoping review is a type of research synthesis used to identify the breadth and depth of the literature. It can be used to map existing knowledge on a specific topic, to inform the design of future research, or to identify areas where further research is needed (Munn et al., 2018). On the other hand, a bibliometric analysis is a review methodology used to analyze the characteristics of the literature (e.g., the number of publications and citations; Miranda & Tolentino, 2023). It can be used to discover patterns and trends, uncover article and journal performance, and explore the intellectual structure of a particular domain (Donthu et al., 2021). Both methods are used to summarize the publication patterns in a body of research. In recent years, there have been a considerable number of studies that use both methods to better explore research trends within a specific field of study (Ellis et al., 2019; Pirri et al., 2020). From a methodological perspective, combining these methods can provide a more detailed account and comprehensive understanding of the literature.

*Study Protocol*

The protocol design is based on the PRISMA-ScR (PRISMA Extension for Scoping Reviews; Tricco et al., 2018), and the process was divided into two steps. First, the study accomplished a scoping review using a methodological framework composed of five stages: (1) identify the research question, (2) identify relevant studies, (3) select the studies, (4) chart the data, and (5) summarize and report results (Arksey & O'Malley, 2005). A scoping review is ideal when the intention is to map the literature and explore the body of research. It is also the first step in developing a research agenda relevant to hackathons and the contextualization of these events in education. Second, from the recovered scoping review results, the study explored the scientific research trends using bibliometric analysis. It complements the scoping review approach because it also aims to map cumulative scientific knowledge. The analysis was composed of four steps: (1) determine the scope and aims, (2) choose the techniques, (3) collect the data, and (4) run the analysis and disclose the findings (Donthu et al., 2021).

*Search Strategy*

The search strategy was developed in July 2022 and executed in August of that year as the first analysis. Results from this search were used to write the first version of the manuscript. After receiving the feedback from peer reviews by January 2023, another search was executed to cover the remaining months of the year 2022 (August to December). Both searches were conducted in the Scopus database using the following query: *TITLE-ABS-KEY (((hackathon OR datathon OR codefest) AND (education OR teaching OR learning)))*. This search query identified publications mentioning the combination of these words in the title, abstract, and keywords. During the second search, the Web of Science database was also queried using the same search strategy. Compared to other indexing databases, Scopus and Web of Science usually have the highest number of documents (AlRyalat et al., 2019). These academic databases cover a wide range of scholarly literature, including journals, books, and conference proceedings. On a side note, Google Scholar was not included because it lacks the quality control needed for its use as a bibliometric tool (Aguillo, 2012). The search results from the two selected academic databases were not restricted in terms of the publication period following the assumption that the hackathon literature is still limited. In selecting the documents, only journal articles, conference papers, and book chapters published in the field of education and written in English were included. Finally, other document types, duplicate records, and irrelevant studies were excluded from the analysis.

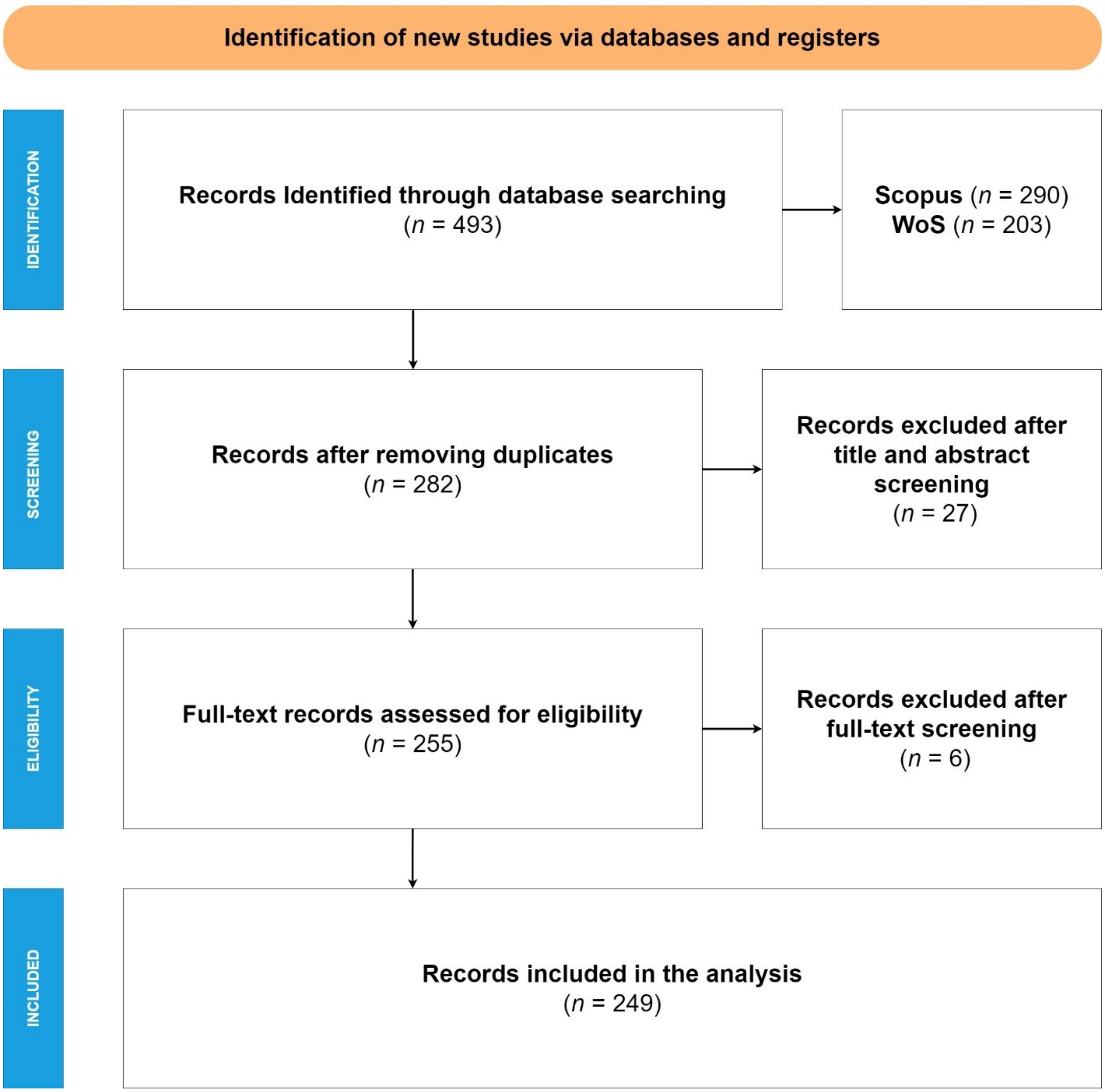


**Figure 2. PRISMA-ScR Flow Diagram for the Study Selection**

*Data Analysis*

All eligible publications and their metadata were exported into *.csv* and *.bib* file formats. The exported documents from the *.csv* file were manually tagged using a custom data extraction workbook and charting system to perform the scoping review. Meanwhile, the *.bib* file was imported to *Posit* (the new name of *RStudio*) to perform the bibliometric analysis using the *bibliometrix* package. This open-source *R* package provides a set of tools for quantitative research in scientometrics and bibliometrics (Aria & Cuccurullo, 2017). The bibliometric analysis technique toolbox by Donthu et al. (2021) was used as a guideline. Finally, the *VOSviewer* software was used to construct bibliometric network visualizations. It was selected because it can automate the process of creating visually appealing and informative visualizations.

# RESULTS

As shown in Figure 2, the database search returned 493 studies from Scopus and Web of Science, which was reduced substantially by 57.20% ($n$ = 282) following the removal of duplicates. Through title and abstract screening, another 27 documents were excluded before the full-text examination. Assessing the full-text articles using the eligibility criteria resulted in six more excluded documents. These excluded papers were hackathon research but not contextualized in education. A total of 249 documents met inclusion criteria and were included in this scoping review and bibliometric analysis. Of these documents, 56.22% ($n$ = 140) were conference papers, 42.17% ($n$ = 105) were journal articles, and the remaining were book chapters ($n$ = 4, 1.61%). Since hackathons are popular in the computing discipline (Garcia, 2022), it is unsurprising that most publications were conference papers. As pointed out by Vrettas and Sanderson (2015), this discipline values conferences as a publication venue more highly than any other academic field.

**Table 1. Main Information on Hackathon Research**

| **Description** | **Results** |
|---|---|
| Timespan | 2014-2022 |
| Sources | 180 |
| Documents | 249 |
| Annual Growth Rate | 41.68% |
| Authors | 1309 |
| Authors of Single-Authored Document | 29 |
| International Co-Authorship | 22.22% |
| Co-Authors per Document | 5.43 |
| Author's Keywords | 808 |
| Document Average Age | 3.1 |
| Average Citations per Document | 6.69 |

*RQ1. What is the general state of hackathon research in the field of education?*

The general information from the analyzed dataset is presented in Table 1. A total of 1,309 authors have published 249 documents with an average of 4.15 co-authors per document published in 180 unique sources. Collectively, the documents accumulated 1,312 citations with a mean of 6.69 citations per document. The literature is on an upward trend with an annual growth rate of 41.68%. As shown in Figure 3, this trend indicates a growing interest in hackathons in education up to 2021, where it has the highest volume of documents published in a year (*n* = 56, 22.49%). However, there was a 17.86% decrease in published papers in 2022 (*n* = 46).

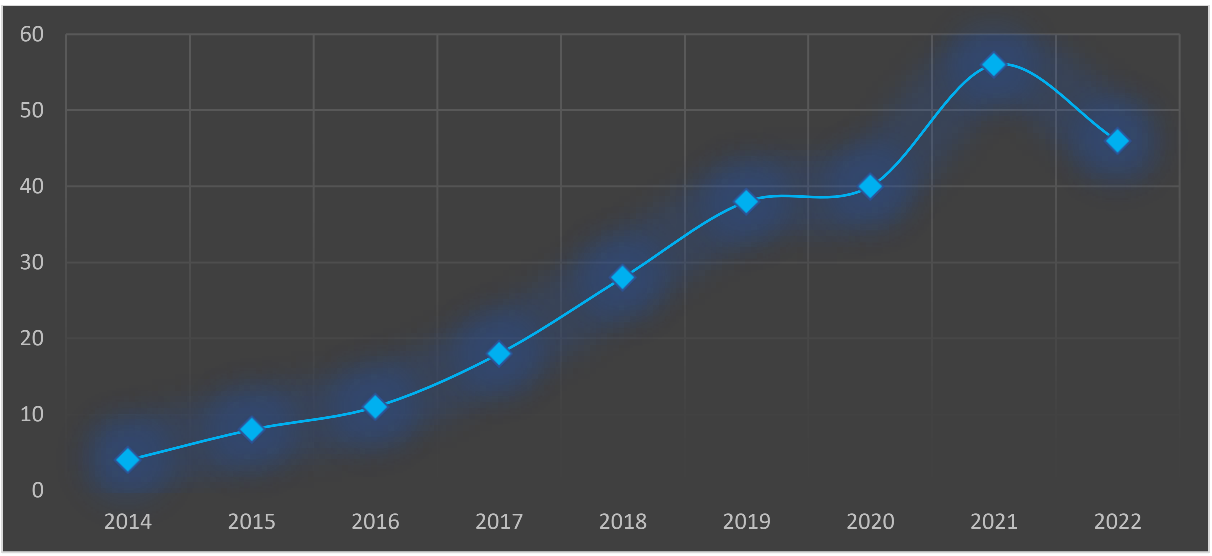


**Figure 3. Annual Publication Trend of Hackathon Research**

*RQ2. Who are the most productive authors, countries, and institutions in this field?*

Authors, institutions, countries, and sources with the highest productivity are presented in Table 2. In bibliometric analysis, productivity analysis is one way to measure the impact and influence of these entities within a particular field of research (Donthu et al., 2021). In terms of the number of publications, Alexander Nolte Leo *(n* = 8) was the most productive author. It is interesting to note that most of his publications were about hackathons conducted outside the academia and used as informal learning opportunities. For instance, his most cited work explored the outcomes of conducting a corporate hackathon with individuals who perceived this time-bounded event as an opportunity to learn and advance their careers (Nolte et al., 2018). Of the 160 institutions involved in the field of hackathon research, the Massachusetts Institute of Technology (MIT) in Cambridge, USA has the most published documents *(n* = 14, citations = 76). The most cited work (citations = 21) affiliated with MIT was the employment of hackathons as a model for cross-disciplinary collaboration and learning in healthcare (Lyndon et al., 2018). Nevertheless, it is noteworthy that while MIT has the most published hackathon research as of 2022, the Harvard Medical School (HMS) has the most citations. Coincidentally, the most cited paper affiliated with HMS is also the hackathon research paper that is the most cited from MIT.

**Table 2. Most Productive Authors, Institutions, Countries, and Publishers in Hackathon Research**

| Categories and Subitems | Documents | Citations |
|---|---|---|
| *Authors* | | |
| Alexander Nolte | 8 | 61 |
| Leo Anthony Celi | 6 | 60 |
| Kiev Gama | 6 | 57 |
| Ari Happonen | 5 | 76 |
| Mairéad Hogan | 4 | 6 |
| *Institutions* | | |
| Massachusetts Institute of Technology | 11 | 76 |
| Harvard Medical School | 8 | 116 |
| Carnegie Mellon University | 8 | 61 |
| Tartu Ülikool | 7 | 53 |
| Universidade Federal de Pernambuco | 6 | 50 |
| *Countries* | | |
| United States of America | 99 | 995 |
| United Kingdom | 24 | 176 |
| Canada | 21 | 150 |
| Germany | 19 | 150 |
| Brazil | 17 | 127 |
| *Publishers* | | |
| ACM | 42 | 402 |
| IEEE | 30 | 201 |
| Springer | 17 | 158 |
| SAGE | 9 | 171 |
| Elsevier | 9 | 50 |

Among the 66 countries that published in the field, the USA has published the most hackathon research ($n$ = 99) and the highest citations ($n$ = 995). This result is unsurprising since college hackathons started in the USA in 2010 (Warner & Guo, 2017). It also has the highest total link strength (57) among the countries, followed by the United Kingdom (29), Germany (28), Spain (21), and Canada (20). Figure 5 presents the co-authorship network of author-affiliated countries using total link strength as the weight. The total link strength represents the strength of the connections between different items in a network. The higher the total link strength, the stronger the connection between the two items. Meanwhile, it is apparent that high-income countries consistently publish hackathon research. One possible reason is that hackathons are concentrated on specific industries (e.g., healthcare, technology, and finance) that tend to be more developed in richer countries. The more developed an industry is, the more opportunities for hackathons to take place. Finally, the international conference proceedings of ACM have the largest volume of any publisher, with 38 (90.48%) of the documents being conference papers.

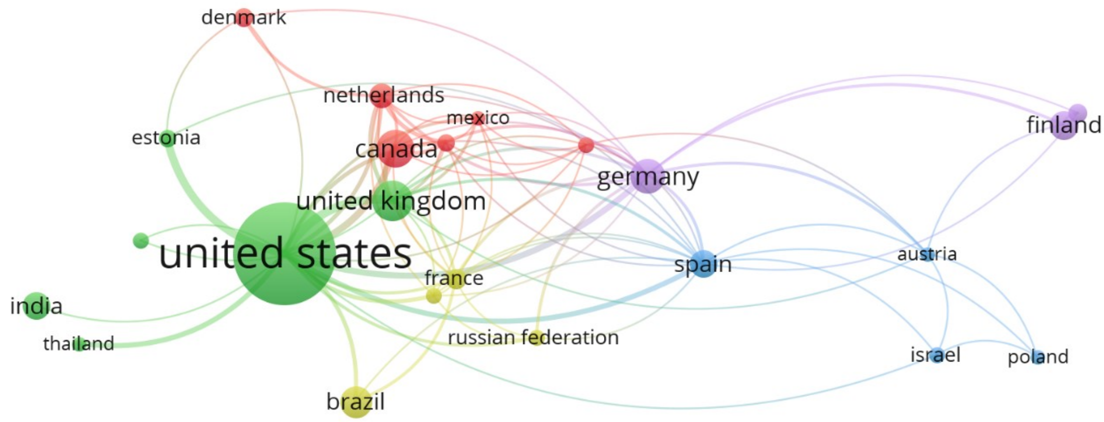


**Figure 4. Co-Authorship Network of Author-Affiliated Countries**

*RQ3. What are the most relevant hackathon publications in terms of citations?*

Citation analysis was conducted to identify the most relevant research on hackathons. In bibliometric analysis, papers with a high number of citations are more relevant and influential. According to Donthu et al. (2021), citation analysis is a science mapping technique that is the most objective and straightforward measure to determine the importance of publications in a research field. Table 3 displays the top ten published documents with the highest citations. The most influential work was the analysis of hackathons as an informal learning platform published in 2016 by Arnab Handi and Meris Mandernach from Ohio State University, USA. As of 2022, it has a total citation of 95 and an annual citation of 13.57. This finding supports a recent assertion that there is still a weak association between hackathons and education and that the education sector has not yet fully embraced hackathons as a formal source of education (Garcia, 2022).

At best, hackathons are conducted as extracurricular activities rather than an integrated component of the curricula. This finding is evident in the second most cited hackathon research, which conducted "StitchFest" as part of a larger collegiate hackathon (Richard et al., 2015). In this event, the participants worked with an Arduino and a set of components to design wearables. With this realization, Garcia (2022) recommended the formal integration of hackathons as a pedagogy at a classroom level. He cited the "Engineering Design Days" as an example where undergraduate engineering programs facilitate in-house hackathon events that replaced their traditional classroom sessions. The third most cited paper also supports this claim by raising a question about how hackathons can be infused into traditional university classes (Warner & Guo, 2017). They noted that one potential advantage of integrating hackathons into classes is an opportunity for teachers to follow up on the projects even after the events are over. In summary, the most relevant hackathon publications revolve around the notion of hackathons as a mode of informal learning. The paper of Gama et al. (2018) (top 9; citations = 26) that suggested hackathon implementations in the classroom has yet to attract the attention of the community.

**Table 3. Highly Cited Hackathon Research in Education**

| Rank | First Author (Reference) | Year | Document Title (DOI) | Total Citations | Annual Citations |
|---|---|---|---|---|---|
| 1 | Arnab Nandi (Nandi & Mandernach, 2016) | 2016 | Hackathons as an Informal Learning Platform (10.1145/2839509.2844590) | 95 | 13.57 |
| 2 | Gabriela T. Richard (Richard et al., 2015) | 2015 | StitchFest: Diversifying a College Hackathon to Broaden Participation and Perceptions in Computing (10.1145/2676723.2677310) | 73 | 9.13 |
| 3 | Jeremy Warner (Warner & Guo, 2017) | 2017 | Hack.edu: Examining How College Hackathons Are Perceived by Student Attendees and Non-Attendees (10.1145/3105726.3106174) | 46 | 7.67 |
| 4 | Jari Porras, (Porras et al., 2018) | 2018 | Hackathons in Software Engineering Education: Lessons Learned from a Decade of Events (10.1145/3194779.3194783) | 43 | 8.60 |
| 5 | Julie K. Silver, (Silver et al., 2016) | 2016 | Healthcare Hackathons Provide Educational and Innovation Opportunities: A Case Study and Best Practice Recommendations (10.1007/s10916-016-0532-3) | 41 | 5.86 |
| 6 | Miguel Lara, (Lara & Lockwood, 2016) | 2016 | Hackathons as Community-Based Learning: A Case Study (10.1007/s11528-016-0101-0) | 38 | 5.43 |
| 7 | Craig Anslow, (Anslow et al., 2016) | 2016 | Datathons: An Experience Report of Data Hackathons for Data Science Education (10.1145/2839509.2844568) | 32 | 4.57 |
| 8 | Sophie Zaaijer, (Zaaijer et al., 2016) | 2016 | Cutting Edge: Using Mobile Sequencers in an Academic Classroom (10.7554/eLife.14258) | 28 | 4.00 |
| 9 | Kiev Gama (Gama et al., 2018) | 2018 | Hackathons in the Formal Learning Process (10.1145/3197091.3197138) | 26 | 5.20 |
| 10 | Jason K. Wang (Wang, Roy, et al., 2018) | 2018 | Institutionalizing Healthcare Hackathons to Promote Diversity in Collaboration in Medicine (10.1186/s12909-018-1385-x) | 22 | 4.40 |

A co-word analysis using author keywords was also conducted to capture the thematic flow of knowledge among these documents. Of the 978 extracted keywords, 95 items passed the threshold criteria of having at least four occurrences in the dataset. On a side note, there is no recommended threshold for co-word analysis as it depends on the size of the dataset. In general, a threshold is used to filter out less relevant or less frequent keywords, and the appropriate threshold value will depend on the level of granularity that is desired in the analysis. It is often determined through trial and error and can be adjusted based on the results of the analysis. Thus, the threshold criteria that were selected offered the best result for the network visualization. The result of this keyword co-occurrence network analysis was presented in Figure 5.

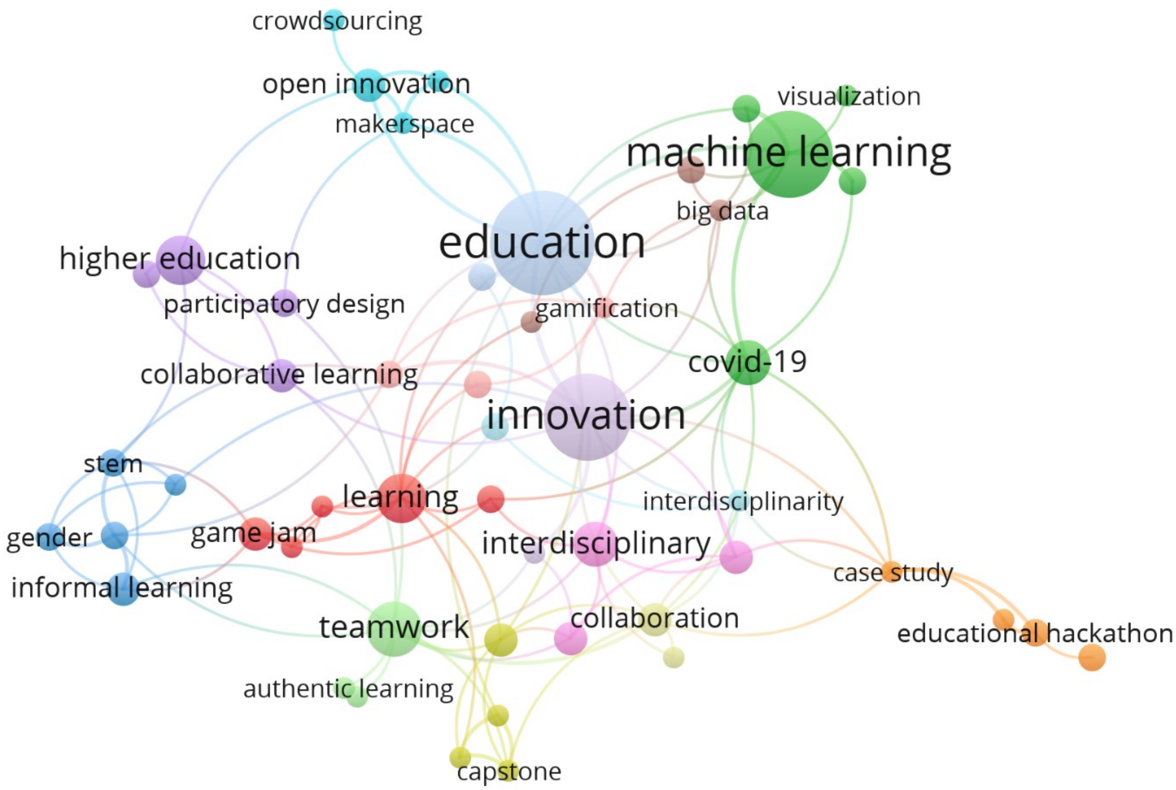


**Figure 5. Author Keyword Co-Occurrence Network Map**

This author keyword co-occurrence network map has a total link strength of 349, which is composed of 11 clusters. Aside from education, which is the context of the bibliometric analysis, it is evident from the result that innovation was a largely studied concept. The innovation cluster was composed of terms, such as creativity, data science, education, gamification, invention, invention development, and students. A word frequency analysis also discovered that innovation was the most occurring word in the dataset (total link strength = 33), disregarding the words “hackathon”, “hackathons”, “datathon”, and “education”. This finding was anticipated since hackathon events are viewed as an innovation contest for developing active education (Yarmohammadian et al., 2021). The fifth most relevant hackathon research in this dataset also implemented hackathons to provide innovation opportunities in the healthcare industry (Silver et al., 2016). In Figure 6, the keyword network visualization produced five clusters where innovation was grouped with the design thinking and innovation contests. Like hackathons, design thinking is also becoming prevalent in the education sector (Revano & Garcia, 2020). Both innovation contests are human-centered approaches to problem-solving although they differ in terms of the implementations, goals, and outcomes. Overall, the result of these co-word analyses is important because the identified keywords indicate the trend of topics of the literature. In turn, this trend can be used in predicting or informing future hackathon research (Donthu et al., 2021).

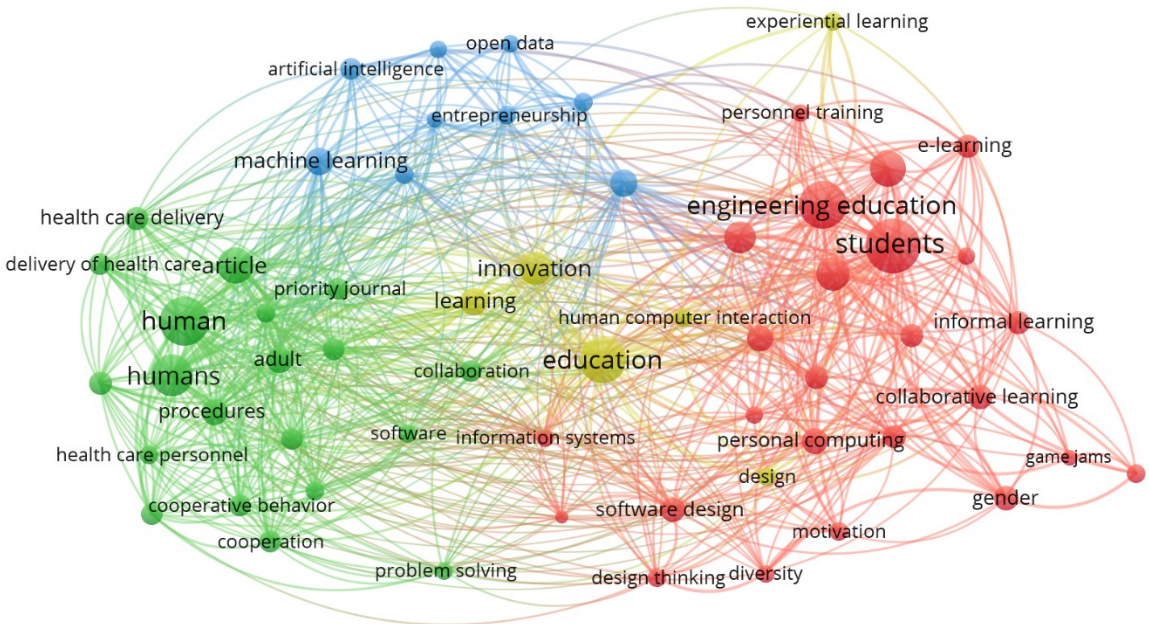


**Figure 6. Keyword Network Visualization with Five Clusters: (1) Education and Pedagogies, (2) Human, Healthcare, and Medicine, (3) Computer Science Concepts and Learning Systems, (4) Design Thinking and Innovation Contests, and (5) Experiential Learning.**

*RQ4. What academic disciplines are used to study educational hackathons?*

The top five academic disciplines were computer science *(n* = 144, 57.83%), social sciences *(n* = 99, 39.76%), engineering *(n* = 62, 24.90%), medicine *(n* = 41, 16.47%), and business *(n* = 21, 8.43%). In computer science, one example is the accession of data science curriculums with integrated hackathon events (Anslow et al., 2016). As these events focused on data and solving problems with a dataset, the authors referred to them as *datathons*. In social science, the research was more focused on learning and pedagogy. For instance, one study explored hackathons as a methodology for an online cybersecurity course (Affia et al., 2022). This study combined design thinking and challenge-based concepts for a one-day hackathon event. In engineering, hackathons were utilized to teach topics that are not core to the engineering discipline. One example is the hack day conducted to foster engagement and increase content knowledge on public health issues (Pakpour et al., 2022). In medicine, innovation is at the core of hackathon implementation. For instance, one study conducted an extended hackathon to make the next generation of healthcare innovators (Wang, Pamnani, et al., 2018). The event was painted as an educational model for teaching foundational skills for medical innovation. Finally, a practice-based approach as a substitute for traditional methods in teaching business education was the inspiration to implement hackathons. One study used hackathons as a pedagogical tool to teach and learn business and entrepreneurial skills (Avila-Merino, 2019). Overall, the result of subject area identification is important in bibliometric analysis because it contextualizes the literature and visualizes the research distribution across different fields.

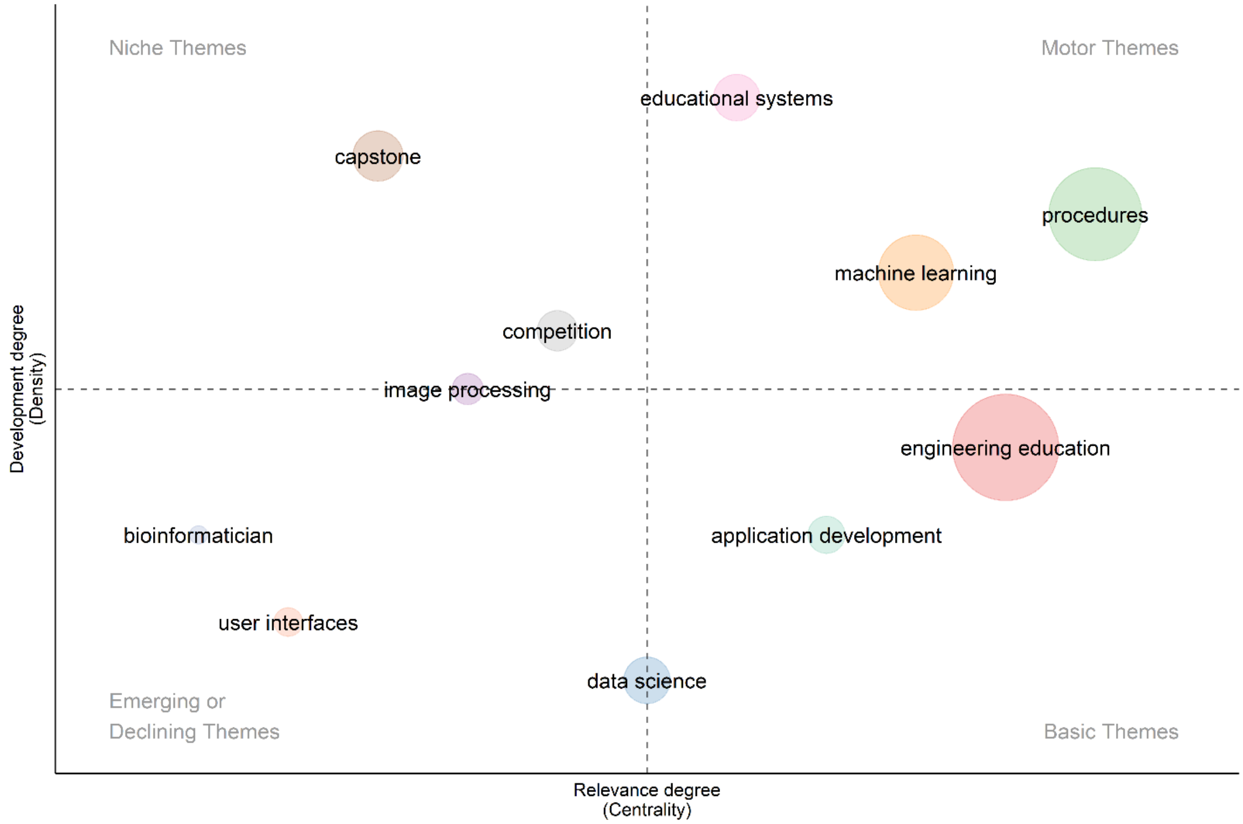


**Figure 7. Strategic Diagram of the Composite Thematic Map**

*RQ5. What are the conceptual structure and the trending topics in this domain?*

As posited by Khare and Jain (2022), the most significant finding of a conceptual analysis using co-word occurrence is the identification of themes and topics. This analysis is important because it highlights what concepts related to hackathon research are underdeveloped, well-established, declining, and emerging. Future research can therefore identify what study needs to be conducted. Figure 7 presents the conceptual structure of the dataset that was distinguished using a composite thematic map (CTM). This diagram presents themes characterized by density (internal strength) and centrality (degree of interaction). Bubbles in the map are keywords with the highest occurrence value and their location is based on the centrality and density of the theme. Each bubble can be classified into four groups and mapped in a two-dimensional diagram. Basic themes in the lower right quadrant are significant yet underdeveloped themes. For instance, engineering education was in this quadrant, but its direction is heading towards motor themes implying that it is a trending topic. These motor themes (e.g., educational systems and machine learning) are well-developed and important for the structure of the hackathon research. On the other hand, niche themes (e.g., capstone and competition) have high density but low centrality, indicating that they are marginally important in hackathon research. As the name suggests, the emerging or declining themes (e.g., user interfaces and bioinformatician) are either emerging or declining because they are low in both relevance and density.

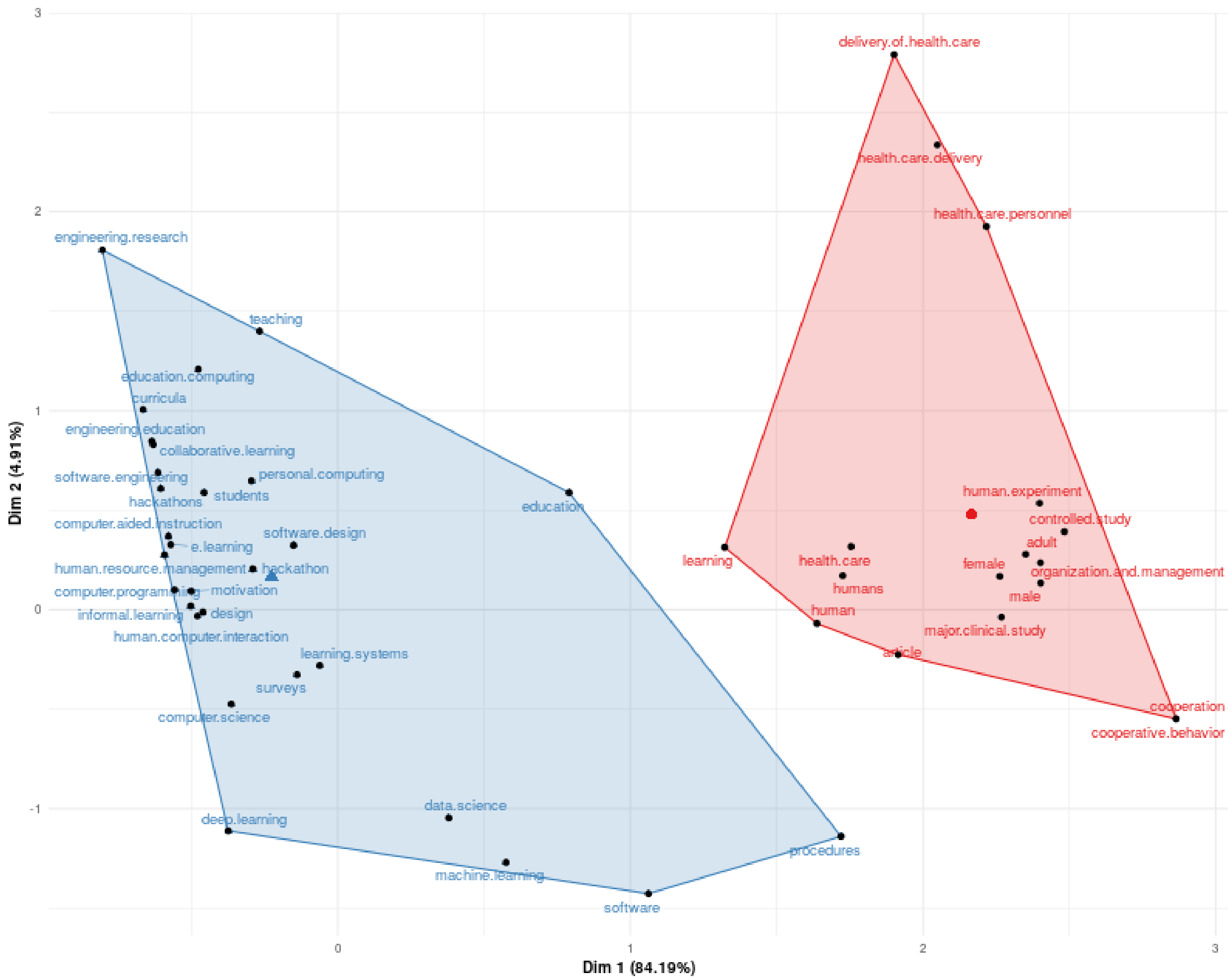


**Figure 8. Conceptual Structure Map Using Multiple Correspondence Analysis**

In addition to a CTM, a conceptual structure map (CSM) was also formulated using multiple correspondence analysis (MCA). A CSM is also a type of visualization used to determine the relationships between different concepts. Unlike CTM which is based on the levels of density and centrality, a CSM plots the general clusters of the research foci. To generate a CSM, prior research recommended using an MCA (e.g., Rejeb et al., 2022). MCA is a multivariate method that analyzes categorical data and identifies patterns and connections. It is used together with a k-means clustering technique to generate clusters that express common concepts (Aria & Cuccurullo, 2017). Figure 8 shows the CSM of the dataset generated using MCA. The analysis automatically created two primary clusters that represent the intellectual structure and research foci of educational hackathons. The most extensive research cluster is highlighted in blue, which was generally represented by computing concepts (e.g., software, machine learning, computer programming, and software engineering). Conversely, the other research cluster highlighted in red revolved around healthcare and human experiments. Both research clusters indicate the numerous studies contributed to the hackathon research by scholars from various disciplines.

## DISCUSSION

Hackathons are becoming increasingly popular as innovation contests where talented individuals can showcase their skills and talents. Like other sectors, education is also slowly and steadily adopting this time-bounded collaborative event to provide students with hands-on, experiential learning opportunities where creativity, problem-solving, and teamwork are valued and promoted. From a macro perspective, hackathon events are used by educational leaders to initiate digital transformation and foster an innovation culture. Nevertheless, the current state of research on hackathon events conducted in educational settings is yet to be identified. Although there is an existing literature review (Olesen & Halskov, 2020), it was not solely contextualized in education. This research gap hinders the possibility of comprehensively understanding this emergent area in educational research. Identifying trends and patterns as well as areas where further research is needed may point researchers to the most pressing questions and problems. If hackathons can offer the benefits of project-based and experiential learning initiatives, it is even more important to map the literature because the education sector is known to be historically slow in embracing innovations (Hoffman & Holzhuter, 2012). This knowledge will give policymakers the evidence they need to make more informed decisions.

This scoping review and bibliometric analysis obtained 249 documents on hackathon research in the education sector. The publication trend exhibited a constant increase with an annual growth rate of 51.67% from 2014 to 2021. This rate was lower (41.68%) if 2022 was included because there was a 17.86% decrease in published papers between 2021 and 2022. For now, it is too early to tell if the academic interest in hackathons will continue to decline in the coming years. Future works should investigate the literature again to determine what the publication trend would be. Consequently, this slowdown in the scientific output of this research area indicates a call for more research attention to ensure the advancement of the field. Constant growth in research is essential to continue expanding our understanding of this potential pedagogy and to improve our ability to address further challenges. More importantly, the education sector will be able to harness the benefits of hackathons more efficiently if it is constantly provided with new knowledge and evidence. Garcia (2022) listed some critical research gaps in the literature that need to be filled, such as drafting guidelines for more inclusive and diverse events, differentiating various hackathon formats, and conducting competitions in non-engineering and non-computing degrees. These potential research avenues attest to the fact that the educational hackathon literature is still limited and needs to be further expanded.

One more important research area that needs further improvement is the integration of hackathons into the curricula as a core component rather than an extracurricular activity. Steglich et al. (2020) asserted that incorporating hackathons into an educational curriculum can promote students' understanding of various technologies and encourage them to develop their problem-solving skills. The citation analysis unfortunately revealed that hackathons as a formal learning environment (Gama et al., 2018) are less relevant than as an informal learning platform (Nandi & Mandernach, 2016). Transforming hackathons into a formal learning experience is therefore warranted. One example is to design challenges or activities that are aligned with the course objectives. Aligning activities with a curriculum provides a clear structure for the hackathon, making it easier for participants to understand what they should be learning and how they can apply it. In addition, hackathon tasks that are created with the course curriculum in mind show greater usefulness in learning and a better connection between academic educational programs and current industrial practices (Affia et al., 2022; Sadovykh et al., 2020). As a managerial implication, schools must create a structured curriculum or syllabus with specific learning objectives and outcomes to guide their students through the hackathon events.

The derivation of hackathons from the tech industry makes it unsurprising that computer science was the most studied area. In most cases, these events were managed as competitions to build a venue for collaborative software development e.g., Mhlongo et al. (2020); (Steglich et al., 2020; Uys, 2020). They are also perceived as a breeding ground for innovation, which was the most used term (word frequency analysis) and the most studied concept (author keyword co-occurrence) in the literature. Meanwhile, engineering education was the most trending topic, indicating the growing implementation of time-bounded collaborative events in the engineering discipline (e.g., Goudswaard et al., 2022). However, engineering was only the third most studied academic discipline and an important yet underdeveloped theme according to the conceptual structure of the documents. These findings indicate that more hackathon studies outside the computer science and engineering disciplines are essential for a more thorough understanding. The same realization was noted in the employment of design thinking (another form of an innovation contest) in higher education (Pakpour et al., 2022; Revano & Garcia, 2020). The curricular integration is especially recommended for disciplines that fall short of engaging their studies in interdisciplinary idea development (Almeida, 2023; Cwikel & Simhi, 2022).

As revealed by the conceptual structure of the dataset, health and medicine disciplines are also starting to leverage hackathons (e.g., Butt et al., 2021; Mevawala et al., 2021). More than half (24/41) of the publications in this academic discipline were published from 2020-2022 during the COVID-19 pandemic. One emerging variation is the online hackathon event, which became more popular because of the school closures (Franco et al., 2022; Happonen et al., 2021; Ulitin et al., 2022). These studies retrofitted these innovation contests and social gatherings to transform them into remote hackathons. In addition to regulating the socioeconomic consequences of the pandemic (Garcia et al., 2023), these events emphasize the important role of young people in terms of ideas and innovations that addresses these social issues and barriers. This realization strengthens the necessity for fostering an innovation culture in education that can transform students into creative and innovative thinkers. Doing so will also contribute to the development of a knowledge economy that is vital to the socioeconomic and societal growth in the developed world (Chen et al., 2018; Edwards-Schachter, 2018; Terstriep & Rehfeld, 2020; Zeb, 2022).

Finally, the number of documents and the co-authorship network shows that the USA is the largest provider of hackathon publications and has the highest total link strength. This finding is unsurprising since hackathons originated in the USA (Warner & Guo, 2017). From a scientific research perspective, a research area that is concentrated in a particular country can pose several consequences. For instance, the body of knowledge may lack diversity in terms of perspectives, methods, and findings. This deficiency can lead to a narrow understanding of the topic and a lack of cross-cultural comparisons. Further, the findings may be more likely to reflect the biases and assumptions of that culture, which can lead to inaccurate or incomplete conclusions. More studies are recommended to be conducted by researchers in other countries. Another interesting pattern is that most hackathon research was published by richer countries (e.g., Germany, Canada, and the United Kingdom). One potential reason is that there are more opportunities for hackathons to take place because the competitions tend to be concentrated on specific industries that are more developed in these nations. This disparity will negatively impact the economy and society of poorer countries if they cannot consistently produce talents who can innovate.

## CONCLUSION

This study carried out a scoping review and bibliometric analysis on the implementation of hackathons in education. As an emergent area of research, understanding the current state of literature and discovering prevalent trends is necessary to inform future hackathon research. From 2014 to 2022, there were 249 documents written by 1,309 authors and published in 180 unique sources. This finding indicates that the educational hackathon literature is still limited and needs to be further expanded. One potential research area that emerged was the transformation of hackathons from an informal to a formal learning environment. As most studies were conducted in computer science, engineering education was the most trending topic, and healthcare was an emerging research cluster, more research attention was consequently suggested to other areas, particularly those that are not actively engaged in innovation activities. Moreover, researchers from least-developed countries were also encouraged. With the conceptual structure emphasizing the crucial role of young people in terms of ideas and innovations, this study strengthens the necessity for fostering an innovation culture in education.

Like any research, this study has some limitations that could be an opportunity for other future research works. First, only Scopus and Web of Science were utilized, and other indexing databases may produce more eligible studies. Other researchers may also consider Google Scholar for gray literature since a simple search of "*hackathon* AND *education*" produced 19,500 results. Second, other search strategies may be used to expand the dataset. A few more studies that did not use the selected keywords may be eligible for analysis. Finally, exploring the intellectual structure by utilizing bibliographic coupling, co-citation, and co-authority techniques may produce interesting findings. However, these analyses were not performed due to a low number of documents. This small sample size may have also undermined the generalizability of the results. Therefore, more scoping reviews and bibliometric analyses are warranted once more studies have been published. Overall, this study offered a concise but global perspective on the current trends of hackathons in educational research and practice. Not only it informs future research but also contributes to the literature by elucidating the significance of hackathons as an educational space for transforming students into creative and innovative thinkers.

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## LET'S COLLABORATE!

If you are looking for research collaborators, please do not hesitate to contact me at mbgarcia@feutech.edu.ph.

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