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NAVIGATING THE GLOBAL LANDSCAPE ON PROJECT-BASED LEARNING AND 21ST-CENTURY SKILLS RESEARCH (2020–2023): A BIBLIOMETRIC ANALYSIS

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ABSTRACT

Purpose – This study aims to conduct a thorough examination and bibliometric analysis of the scholarly articles on PjBL (Project-Based Learning) and 21st-century skills published from 2020 to 2023. The analysis will specifically concentrate on the global distribution of these articles and identifying any prevailing research patterns or trends.

Methodology – Utilizing "PjBL" and "21st-century skills" as search terms, the Scopus database was employed for the analysis

encompassing annual publications, nations, institutions, authors, journals, references, and keywords in the field. This analysis was facilitated by VOSviewer and Microsoft Excel 2019 software.

Findings – There has been a significant increase in publication volume between 2020 and 2023. Among the 2,472 articles within the Scopus database by the end of October 2023, Indonesia emerged as the primary contributor of publications among all nations. The VOSviewer indicates that the key issues revolve around, project-based learning (PjBL), pedagogy, critical thinking, education, sustainability, higher education, and 21st-century skills.

Significance – A comprehensive analysis of the global landscape concerning project-based learning (PjBL) and, between 2020 and 2023, aims to uncover pivotal trends, emerging issues, influential authors, and seminal works in educational research. The anticipated outcomes hold the potential to offer multifaceted insights into PjBL and 21st-century skills, contributing to the exploration of innovative educational methodologies. Additionally, this study's investigation of specific research inquiries aims to provide a holistic overview, further enriching the understanding of these crucial educational paradigms.

Keywords: Project-based learning analysis, 21st-century skills research, bibliometric analysis, scopus database publications, global educational trends.

INTRODUCTION

Advancements in technology, globalization, and shifting social issues have brought about significant changes in education, prompting adaptations in curricula, integration of technology, cultural exchange, collaborative initiatives, and emphasis on skills and professional development (Grassini, 2023). In the modern era, education is expected to equip individuals with the skills and knowledge necessary to thrive in contemporary society (Karaca-Atik et al., 2023; Turiman et al., 2012). However, there remains a challenge in ensuring that educators possess the required 21st-century skills and are equipped with effective teaching approaches and strategies for professional development (Kim et al., 2019).

Project-Based Learning (PjBL) emerges as a progressive teaching method aimed at bridging traditional classroom learning with the

dynamic demands of the modern world, with a focus on cultivating 21st-century skills (Markula & Aksela, 2022; Saimon et al., 2023). While Zhang and Ma (2023) found limited significance in PjBL's direct impact on improving student learning outcomes, the method fosters student engagement through constructive dialogues and encourages independently exploration of real-life issues, nurturing a genuine passion for acquiring knowledge. Despite PjBL's widespread popularity of across educational levels and settings, Kokotsaki et al. (2016) emphasizes the importance of student involvement and active participation in interdisciplinary projects spanning various subjects, fostering autonomy, and passion for learning. Recognized as a potent teaching technique, PjBL offers valuable insights for enhancing educational practices (Bytyqi, 2022; Turgut, 2008).

Gaps in research have been identified regarding the relationship between PjBL and 21st-century skills particularly in terms of scope and integration, extensive reviews, and comprehensive exploration. While previous research have extensively examined PjBL within the context of science, technology, engineering, and mathematics (STEM) education, there is a pressing need for a broader understanding that encompasses diverse topics and research trends (Zhan et al., 2022) across various disciplines and educational levels. Additionally, there is a call for more extensive reviews across disciplines and educational levels to promote the development of 21st-century skills (Matahari et al., 2023). Recent studies has shown positive impacts of PjBL on students' critical thinking, problem-solving, and creativity (Anasi & Harjunowibowo, 2022). However, leveraging meticulous bibliometric analysis, this study aims to address the identified gaps in understanding the relationship between PjBL and 21st-century skills, offering valuable insights into knowledge organization and patterns within the education sector (F. Zhang et al., 2022).

The bibliometric analysis conducted in this study is anchored in the aggregation of scholarly articles sourced from the Scopus database, serving as the primary repository for this research endeavour. This comprehensive review process involved compiling pertinent papers and extracting data, including titles, abstracts, and relevant information, using specified keywords and temporal constraints. Subsequently, the amassed data underwent meticulous analysis facilitated by the VOSviewer program—a robust software tool

essential for generating and visualizing network maps derived from scientific articles, journals, authors, research entities, nations, keywords, and concepts. Through diverse linkages like co-authoring, co-occurrence, citations, and other relationships, VOSviewer enables the visualization of interconnected elements within these networks. This approach significantly contributes to the existing literature by curating a comprehensive catalogue of articles, categorizing them based on distinctive characteristics, and employing an inductive methodology to explore current scenarios, advantages, and challenges associated with PjBL and 21st-century skills.

This research aims to provide a comprehensive bibliometric analysis of the global landscape regarding PjBL and 21st-century skills. The study endeavours to analyze recent literature from 2020 to 2023 to identify significant trends, emerging issues, influential authors, and critical works in educational research. The expected results of this study will provide various perspectives on PjBL and 21st-century skills, contributing to the discovery of innovative methods to enhance the quality of education. The study also investigates specific research inquiries to provide a complete overview.

RQ 1: What is the temporal distribution and growth rate of publications related to PjBL and 21st-century skills between 2020 and 2023?

RQ 2: How does the regional distribution specifically identify nations actively engaged in research related to PjBL and 21st-century skills between 2020 and 2023?

RQ 3: Which specific research topics are most frequently referenced by authors concerning PjBL and 21st-century skills?

RQ 4: Are there notable variations in research topics related to PjBL and 21st-century skills among different countries or regions?

RQ 5: To what extent do subject areas intersect or overlap within the literature on PjBL and 21st-century skills?

RQ 6: How are published papers on PjBL and 21st-century skills distributed among various institutions or organizations?

RQ 7: Which journal(s) demonstrate the highest prevalence or readership regarding publications on PjBL and 21st-century skills?

RQ 8: Who are the most influential or highly cited authors in the field of PjBL and 21st-century skills?

RQ 9: What is the extent of citation and co-citation patterns among publications in the realm of PjBL and 21st-century skills?
RQ 10: What is the present study's focus regarding conducting a co-occurrence analysis of keywords?

LITERATURE REVIEW

Project-Based Learning (PjBL)

The convergence of PjBL and the development of 21st-century skills has become a focal point of academic inquiry within the dynamic landscape of modern education. This study undertakes a thorough examination of global research endeavours conducted between 2020 and 2023 through bibliometric analysis, aiming to uncover trends, patterns, and significant contributions within PjBL and 21st-century skills, providing valuable insights for educators, researchers, and policymakers.

PjBL stands as an innovative teaching approach focusing on student autonomy and engagement in real-world projects (Bell, 2010; Mora et al., 2020). At its core, PjBL fosters the development of essential skills aligned with the demands of the 21st century (Darling-Hammond et al., 2020; Krajcik & Shin, 2014). Active student involvement in collaborative endeavors and inquiry-based learning underpins PjBL's capacity to nurture critical thinking, communication, teamwork, and digital literacy skills (Guo et al., 2020) making it a fundamental component of the global educational landscape.

A comparative analysis of various definitions and models of PjBL proposed by experts is necessary to identify their similarities and differences (Chu, 2011; Markula & Aksela, 2022) reflecting the diversity and complexity of PjBL implementation in diverse educational settings. Therefore, further research and investigation into the nuanced aspects of this teaching method are warranted.

The integration of PjBL into educational practices represents a contemporary pedagogical innovation gaining momentum due to its alignment with constructivist ideologies and experiential learning principles (Bell, 2010). Notably, PjBL emphasizes student autonomy and collaborative problem-solving, exemplified by engaging students in practical projects that reflect real-life situations (Meng et al., 2023).

The theoretical framework of PjBL encompasses various essential elements such as authentic challenges, driving questions, partnerships, and reflective practices forming a solid foundation that integrates theoretical and practical dimensions (Markula & Aksela, 2022).

A positive correlation exists between understanding PjBL and the development of 21st-century skills, crucial for students' growth in this modern era (Darling-Hammond et al., 2020). By actively engaging in self-directed learning through investigative processes and collaborative efforts, students utilize PjBL to acquire critical qualities such as critical thinking, communication, teamwork, and digital literacy (Guo et al., 2020; Haleem et al., 2022; Kocak et al., 2021; Reddy et al., 2023; Turiman et al., 2012; E. van Laar et al., 2019; Ester van Laar et al., 2017, 2020). This synthesis bridges theoretical aspects with practical implementation, emphasizing the elements influencing the application of PjBL in various educational settings.

Nevertheless, the academic discourse surrounding PjBL encompasses multiple definitions and models proposed by specialists, necessitating thorough scrutiny. To illuminate similarities and discrepancies, a comparative analysis of these various conceptualizations is crucial (Chu, 2011; Markula & Aksela, 2022; Meng et al., 2023). Furthermore, comprehending the mechanisms driving the effects of PjBL requires an investigation into prominent hypotheses and frameworks. Developing a broad understanding of the main conceptual paradigms governing PjBL procedures is essential (Hallermann et al., 2011).

The academic discourse surrounding PjBL is characterized by numerous definitions and models proposed by experts, demanding meticulous examination and comparative analysis (Chu, 2011; Markula & Aksela, 2022; Meng et al., 2023). Investigating the dominant hypotheses and frameworks is imperative to comprehend the mechanisms influencing the implementation effects of PjBL (Hallermann et al., 2011). An in-depth understanding of the primary conceptual paradigms governing PjBL procedures is fundamental to advancing scholarly comprehension in this domain.

This study enhances the positioning of PjBL practices within academia by scrutinizing their temporal implementation, regional scope, and prevalent subjects of inquiry (RQ 1-4) (Jingfu & Zhixian, 2002; F. Zhang et al., 2022; L. Zhang & Ma, 2023). The research questions are designed to address knowledge gaps and contribute to academic

discussions including the co-occurrence of keywords to identify significant trends, emerging issues, influential authors, and notable works (Baran et al., 2018; Solihin et al., 2021). This study endeavor aims to refine and consolidate the role of PjBL practices in scholarly environments, aligning with the overarching goal of investigating their impact on the acquisition of 21st-century skills.

21st-Century Skills

The emphasis on advancing skills is paramount in human resource training in the 21st-century, given the significant increase in knowledge, particularly in science and technology, and its profound importance to human existence (R. Zhang et al., 2023). Consequently, Indonesia must nurture a cohort excelling in critical thinking, problem-solving, communication, cooperation, and creativity, commonly to as 4C talents (Thornhill-Miller et al., 2023). The rapid evolution of educational technology in the century has presented new opportunities and challenges distinct from previous eras (Hwang et al., 2015; Silber-Varod et al., 2019; Voogt & Roblin, 2012). This condition pertains to selecting appropriate classroom learning methods to assist students in adapting to the demands of the 21st-century (Amelia & Santoso, 2021; Haleem et al., 2022; Puspitarini & Hanif, 2019). Education in the 21st-century has become more accessible, efficient, and affordable (Saavedra & Opfer, 2012). Characterized by classrooms tailored to students' needs and personalized learning approaches, 21st-century education aims to prepare learners more effectively for life than merely for employment (Gajjar, 2013).

In the 21st century, educational institutions are poised to implement project-based curricula that involve active student participation in addressing real-world issues and topics significant to humanity (Malik, 2018; Stehle & Peters-Burton, 2019). Students exert a considerable influence on knowledge creation (Bada & Olusegun, 2015; Golder, 2018), and the changes in education examined in this study are highly relevant to the current generation, which has grown up with digital technology and regularly uses devices like computers, video games, digital music players, cell phones, and video cameras (Prensky, 2001). PjBL aligns with constructivist theory, emphasizing learning as an individual process where learners seek to understand and derive meaning from information. PjBL serves as an exemplary approach (Bada & Olusegun, 2015; Jumaat et al., 2017; Liu, 2010). Recognized

for its innovation and student focus, PjBL develops students' capacity to conduct investigations, research, and project creation, equipping them with technological skills and problem-solving abilities (Rahmania, 2021; Solihin et al., 2021). This pedagogical approach underscores students' active engagement and the importance of their actions, enabling learners to achieve autonomy (Baran et al., 2018; Bell, 2010; Holubova, 2008; Kizkapan & Bektas, 2017).

In the 21st century, technology aids students in safe and efficient exploration and experimentation (Kokotsaki et al., 2016). Implementing PjBL in classrooms has notably enhanced students' problem-solving abilities (Nurhidayah et al., 2021). To effectively apply PjBL, educators must possess the capacity to influence, inspire, and guide students through a series of activities centred on the 4C framework: critical thinking and problem-solving, creativity and innovation, collaboration, and communication (Kingsley & Grabner-Hagen, 2015; Kokotsaki et al., 2016; Nisak & Yulkifli, 2020; Ester van Laar et al., 2017). These activities aim to bolster interpersonal competence, particularly emphasizing the skills and attitudes required for success in the contemporary era. Additionally, the activities encompass the development of personal and social aptitudes, the dissemination of information, values, and knowledge, as well as active participation in society (González-salamanca et al., 2020). Several studies indicate that PjBL is an effective method to foster the growth of 21st-century skills (Artama et al., 2023; Khafah et al., 2023; Matahari et al., 2023).

This study clarifies the fundamental concepts of PjBL, its incorporation into 21st-century skills, and the necessity for a detailed analysis of different definitions and theoretical frameworks. Based on precise research objectives, the following analysis is expected to substantially contribute to enhancing academic knowledge, filling in gaps, and improving the implementation of PjBL in educational environments.

METHODOLOGY

Data Sources

Scholarly publications related to PjBL and 21st-century skills were obtained from the Scopus database, which houses a comprehensive

collection of 2,472 peer-reviewed academic journals spanning more than 25 subject areas. These subject areas include but are not limited to Social Sciences, Environmental Science, Agricultural and Biological Sciences, Materials Science, Multidisciplinary, Biochemistry, Genetics and Molecular Biology, Toxicology, Neuroscience, Immunology, and Microbiology. The database also encompass open-access journals and is widely utilized for bibliometric analysis. In addition, the database offered access to Crucial information such as the author's place of origin, affiliation, keywords, and references for each publication were accessible, which were necessary for this study.

Search Strategy

On October 25, 2023, a keyword search was conducted in the Scopus database using the query TS = ("Project-Based Learning" AND "21st-century skills"). The search yielded a total of 2,472 articles. Publications included in this study were limited to those published between 2020 and 2023, resulting in 1,569 publications. To refine the search, papers were categorized and filtered within the scope of Social Sciences, resulting in 1,124 publications. Subsequently, literature selection focused exclusively on scientific articles published in English, resulting in a corpus of 847 publications. Notably, the scope of this research was limited to papers written in English. A comprehensive search targeting open-access articles in final form yielded 500 publications. Furthermore, the PRISMA declaration's standardized process was employed to assess publications, as illustrated in Figure 2.

Data Analysis

The study utilized bibliometric analysis methodology within a library setting. Bibliometric analysis involves scrutinizing publication distribution to evaluate articles' impact on knowledge advancement across various fields, employing statistical methods to provide a comprehensive overview of the subject (van Eck & Waltman, 2010). Using secondary data, this research focused on articles concerning PjBL and the acquisition of 21st-century skills. The Scopus Database was searched using the keywords "Project-Based Learning" AND "21st-century skills," limited to publications between 2020 and 2023. Initially 1,569 articles were gathered, and subsequent filtering focused on retrieving a more specific set, resulting in 500 papers selected for further analysis, confined to the Article and Journal categories.

These selected documents were exported in RIS format and analyzed using the VOSviewer (Version 1.6.20) and Microsoft Excel 2019. VOSviewer is a software designed to visually represent and analyze bibliometric investigation findings, encompassing countries, journals, and authors using citation, co-citation, or co-authorship connections. It also provides text mining capabilities for constructing and visualizing co-occurrence networks comprising significant phrases retrieved from a corpus of scientific literature (van Eck & Waltman, 2010). Scientific knowledge mapping enables a comprehensive understanding of research hotspots and developmental trajectories within each field of the knowledge system, facilitating the prediction of future trends (Chen, 2004).

The data analysis technique employed in this study involved using the bibliometric mapping results obtained from the VOSviewer tool, utilizing Co-occurrence computations. Co-occurrence analysis employs a statistical method to ascertain research topics by establishing a stronger association between two keywords when they frequently appear together (van Eck & Waltman, 2010). In this analysis, VOSviewer used the binary counting method to extract titles and abstracts of articles, considering each word identified with one or more themes as a single unit. The term had to appear at least five times to be displayed, indicating that only words with a relatedness of five or higher would be shown. Figure 1 highlights the sequence of data collection and processing methods implemented.

Figure 1

Data Collection and Processing Methods

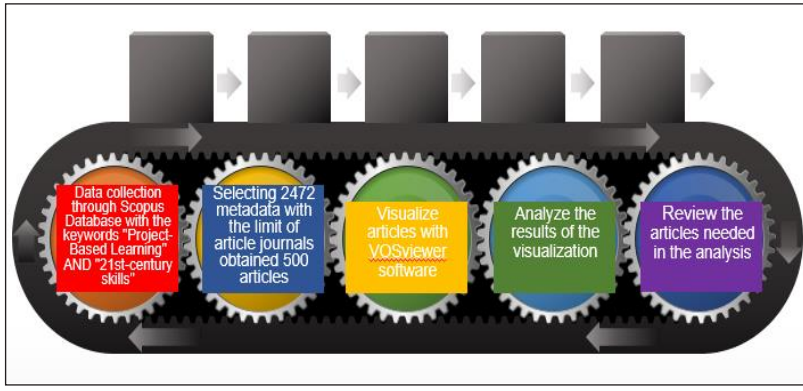
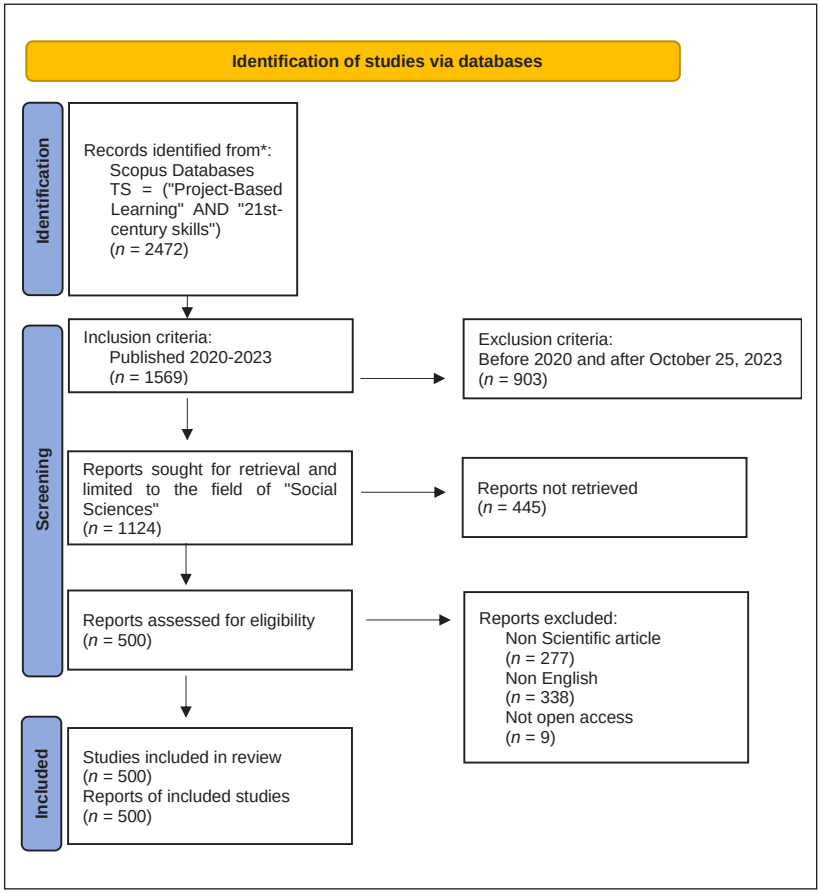


Figure 2

Flowchart According to the PRISMA Declaration (McKenzie JE et al., 2021)



RESULTS

Temporal Distribution

Figure 3 depicts the temporal distribution of publications and citations from 2020 to October 2023. The relationship between the increase in publications and citations demonstrates two distinct stages: sluggish growth and rapid growth. This pattern remains stable until the year

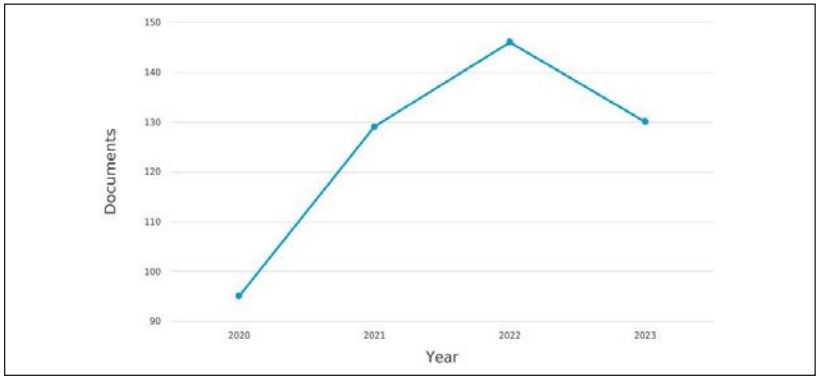
2021, serving as the cutoff point. From 2020 to 2021, the initial phase marks the emergence of "PjBL" and "21st-century skills" in the relevant domain. The graph shows a gradual increase in the number of publications during this period: 95 publications in 2020, 129 publications in 2021, 146 publications in 2022, and a slight decline to 130 publications in 2023. This trend shows a slow increase at a rate of less than 125 publications per year. Citation metrics generated by the Publish or Perish software for 2020–2023 recorded 2,435 citations across 500 documents. This translates to an average of 811.67 citations per year, 4.87 per paper, and 919.96 per author. The average number of articles per author was 203.50, while the average number of authors per paper was 3.16. The h-index was determined to be 22, indicating 22 publications with at least 22 citations each. The g-index, considering the distribution of sources across all publications, was calculated as 33.

Additionally, the hI-norm, representing the number of publications with at least 12 citations each, is determined to be 12. The hI-annual value, indicating the number of publications with at least four sources each annually, is calculated as 4.00. The hA-index, considering the number of authors with at least h citations, is calculated as 11. Furthermore, the number of papers with at least 1, 2, 5, 10, and 20 sources (ACC >= 1,2,5,10,20) are recorded as 320, 201, 17, 18, and 4, respectively.

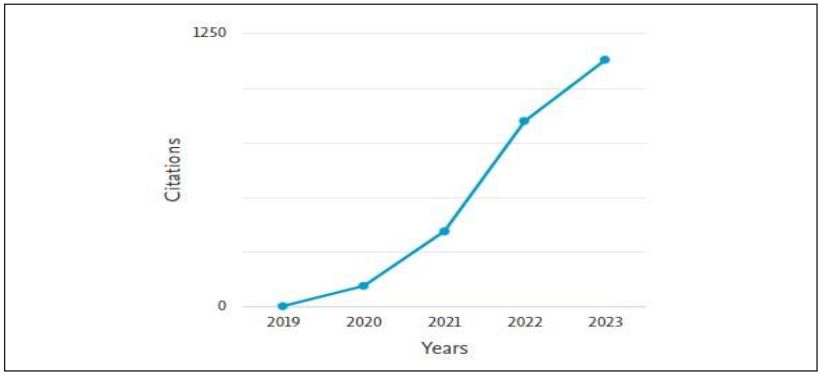
Analyzing the temporal distribution and citation metrics from 2020 to October 2023 offers comprehensive insights into the trajectory of publications centred around 'PjBL' and '21st-century skills.' The observed pattern of publication growth, marked by an initial rise, a peak, and a subsequent decline, illustrates the evolving scholarly interest in these domains. Additionally, the citation metrics highlight the impact and visibility of these publications within the academic landscape. These findings provide a detailed understanding of the growth dynamics and scholarly impact of works related to 'PjBL' and '21st-century skills' over the specified time frame, effectively addressing RQ1 regarding the temporal distribution and growth rate of publications in this field.

Figure 3

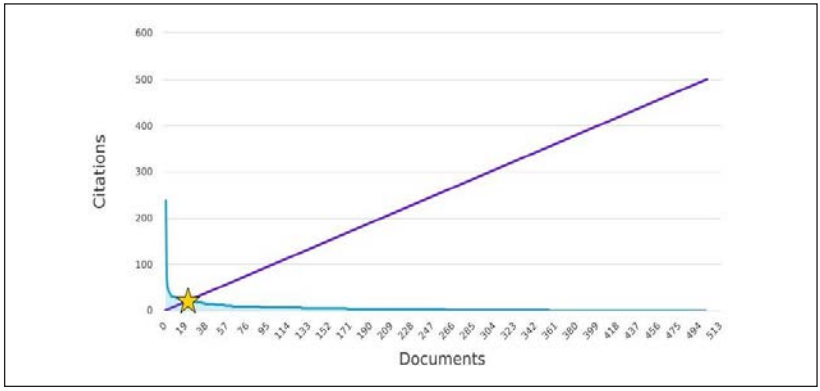
Temporal Distribution



(A) Publication distribution from 2020 to 2023 (Scopus, 2023h)



(B) Citation distribution from 2020 to 2023 (Scopus, 2023a)



(C) A citation overview for a set of 500 documents (Scopus, 2023b)

Regional Distribution

Table 1 outlines the top 16 countries leading in publications from 2020 to 2023 within the realms of PjBL and 21st-century skills. Indonesia notably emerges as a significant contributor, presenting 155 articles that garnered a substantial cumulative citation count of 502 instances and a link strength of 12, representing 31 percent of the total 500 compiled publications. This robust performance positions Indonesia prominently at the forefront of scholarly contributions. However, a deeper analysis of citation frequencies among nations reveals intriguing disparities. While the United States amassed 328 citations and the Netherlands accrued 303 citations despite fewer publications, emphasizing their considerable influence, Turkey and Thailand, with relatively limited publication counts, gained significant international recognition with 98 and 114 citations, respectively. This illustration underscores their research's global impact and recognition despite their smaller contributions to the overall publication count. Such variations in citation frequencies among nations provide nuanced insights into the influence and reach of scholarly work beyond sheer publication volume.

Understanding these disparities in citation frequencies among nations underscores the need for a deeper examination of international collaborations within scholarly domains. An insightful way to explore these collaborative networks is through network visualization maps, illustrating connections among countries in scholarly endeavours. These visualizations provide valuable insights into nations' collaborative patterns and interactions in exploring PjBL and 21st-century skills. The extent and nature of international collaboration can be discerned by analyzing these network maps, illuminating the dynamics and contributions of different countries in advancing knowledge within this field.

Table 1

Countries with the Most Publications in the Field of Project-Based Learning and 21st-Century Skills (2020–2023)

Rank	Country/ Region	No. of Articles	% N= 500	No. of Citations	Total link strength
1	Indonesia	155	31	502	12
2	United States	52	10.4	328	1
3	Malaysia	29	5.8	101	4
4	Spain	25	5	91	0
5	Turkey	25	5	98	3
6	Thailand	22	4.4	114	1
7	Finland	20	4	103	5
8	China	18	3.6	91	1
9	United Kingdom	17	3.4	125	1
10	South Africa	14	2.8	81	2
11	Saudi Arabia	13	2.6	55	0
12	Australia	12	2.4	69	1
13	Israel	12	2.4	58	0
14	Portugal	12	2.4	98	0
15	Netherlands	10	2	303	0
16	Taiwan	9	1.8	38	0

Figure 4 presents a network visualization map illustrating the patterns of international collaboration among various countries. Each point signifies collaboration among nations, with the frequency and thickness of the connection indicating the diversity and strength of different levels. A high degree of interconnectivity among nodes across all nations, suggests a prevalent culture of collaboration among countries. Indonesia occupies a central position within this collaborative network, demonstrating strong connections with numerous nations. Some countries show a growing level of engagement in research, indicating evolving collaborative efforts.

This connectivity observed in the network map mirrors the publication landscape seen in Figure 5, where Indonesia leads prominently with 155 publications from 2020 to 2023. The pronounced collaborative links (showcased in Figure 4) potentially contribute to Indonesia's higher research output, reflecting the impact of these partnerships on publication outputs. Additionally, while the United States exhibits an upward trajectory in publications, its position in the collaborative

network suggests growing collaborative efforts, potentially influencing its increased research productivity (Figure 5).

Figure 5 illustrates the geographical distribution of the top ten countries regarding publications between 2020 and 2023. Indonesia leads with 155 publications, followed closely by the United States, Malaysia, Spain, and Turkey, initiating significant efforts in 2020. Other nations, including Thailand, Finland, China, the United Kingdom, and South Africa, consistently contributed substantially to research in this field.

Figure 4

Network Visualization Map of International Collaboration Among Countries, and Documents by Country or Territory (Centre for Science and Technology Studies, 2023)

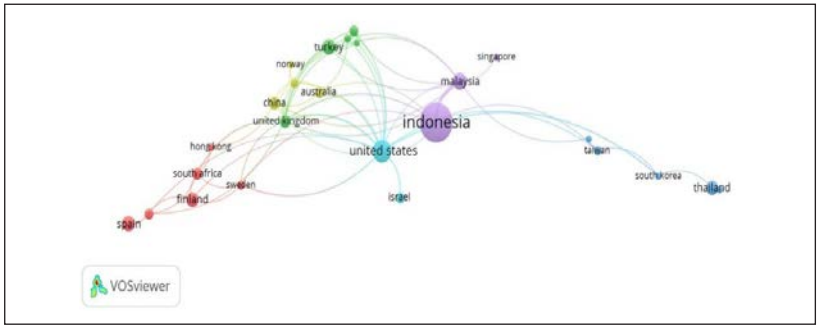
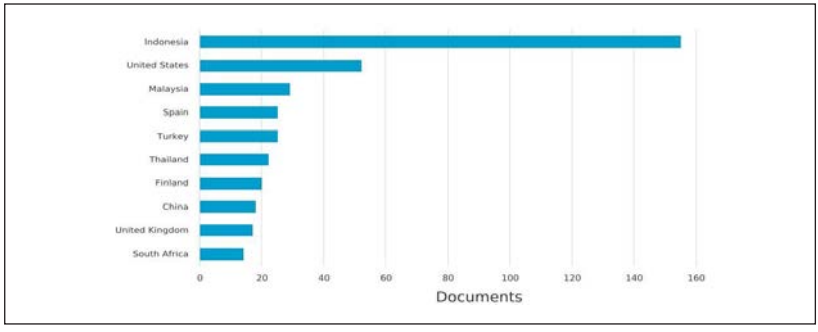


Figure 5

Network Visualization Map of International Collaboration Among Countries, and Documents by Country or Territory (Scopus, 2023e)



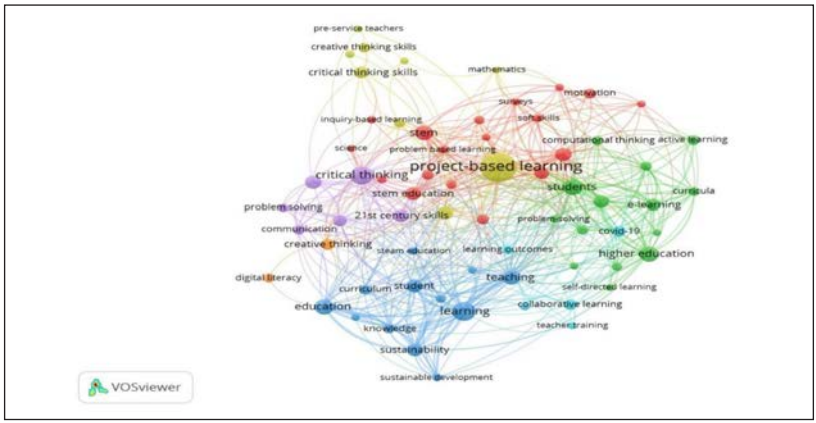
The interplay between regional publication distribution and international collaborations in PjBL and 21st-century skills research from 2020 to 2023 unveils compelling insights. Figures 4 and 5 highlight Indonesia's leading role in publications and collaborative networks, displaying robust connections with numerous countries. Despite differing publication volumes, discrepancies in citation frequencies emphasize global recognition of work from countries such as the United States, the Netherlands, Turkey, and Thailand. Understanding these relationships provides crucial insights into the active engagement of nations in advancing knowledge in this domain, aligning directly with RQ2's focus on identifying the actively involved countries during this period.

Analysis of Research Topics in Various Countries

The primary themes within the accumulated articles in the database were analyzed to identify significant research themes. High-frequency themes within publications were identified using keyword co-occurrence analysis. Furthermore, this study's analysis can also unveil terms associated with the author's field of study. Figure 6 illustrates the network visualization map of research themes. This visualization presents seven distinct clusters, each represented by a unique colour. These clusters encompass various topics including artificial intelligence, engineering education, high school students, higher order thinking skills (HOTS), inquiry-based learning, motivation, problem-based learning (PBL), PjBL, robotics, science, science education, science learning, soft skills, STEM, STEM education, and surveys (depicted in red). Additional themes represented in green include curriculum, instruction, innovation, knowledge, learning, project-based learning, questionnaire surveys, STEAM education, students, sustainability, sustainable development, and teaching. Dull Green depicts themes such as communication skills, creative thinking skills, critical thinking skills, elementary school, gender, mathematics, pre-service teachers, problem-based learning (PBL), and PjBL. Purple represents themes related to collaboration, communication, creativity, critical thinking, and problem-solving. Light blue signifies collaborative learning, COVID-19, learning outcomes, teacher education, and teacher training. Lastly, orange represents creative thinking and digital literacy.

Figure 6

Network Visualization Map of Research Topics (Centre for Science and Technology Studies, 2023)



This study conducted a comparative analysis of keyword frequency within the contexts of project-based learning and countries' emphasis. The investigation revealed significant similarities in both areas. However, substantial variations were observed in policy priorities and implementation. Additionally, clustering maps depicting the distribution of study subjects across different countries exhibited striking differences in focus and clustering pattern, enabling identification of distinctions among these nations. The study primarily focused on the top ten countries with the most publications, categorizing them into four distinct clusters, as illustrated in Figure 6.

Different groups of countries were visualized using a unique colour scheme. Cluster 1, represented by red, includes Australia, Indonesia, and the United Kingdom—discussing active learning, COVID-19, e-learning, higher education, learning outcomes, motivation, online learning, PjBL, science education, and students. Cluster 2, denoted by the colour green, encompasses Malaysia, Norway, and Turkey, focusing on blended learning, collaborative learning, communication skills, design thinking, HOTS, PBL, science learning, and self-directed learning. Cluster 3, characterized by blue, includes Finland, South Africa, and Sweden, discussing computational thinking, creative thinking, digital literacy, education, learning, mathematics, problem-solving, soft skills, and sustainability. Lastly, Cluster 4, distinguished by dull green features Thailand, exploring collaboration,

communication, creativity, critical thinking, problem-solving, PjBL, and STEAM education.

The study's results address research questions (RQ3 and RQ4) by meticulously unravelling the prevalent research topics linked to PjBL and 21st-century skills. The research illuminates the themes frequently referenced by authors across various countries through comprehensive analysis and visualization. The findings distinctly showcase seven clusters representing a spectrum of themes: artificial intelligence, STEM education, PBL, communication skills, and digital literacy. This comprehensive breakdown identifies the most referenced topics and reveals nuances and disparities in focus among nations.

Analysis of the Subject Area

Table 2 Figure 7 depicts the evolving trajectory of research themes in PjBL and the development of 21st-century skills from 2020 to 2023. This progression is characterized by a broadening scope and increased diversification, highlighting the symbiotic relationship between research themes, participating disciplines, and disciplinary development. The integration of knowledge from multiple disciplines is emphasized, addressing the development of human behavior and concerns related to student instruction and learning, catalyzed by advancements in technology.

The expansion and diversification of PjBL-related research are evident in Table 2, which clusters related subject areas encompassing education, technology, and psychology. Each cluster encapsulates a group of subjects sharing thematic similarities or academic focus. Within Cluster 1, "Thinking skills and creativity" emerges as the most frequently linked and strongly associated area with a link strength of 2,569. Despite having a citation count of 137, which might not be the highest among individual cases, its link strength indicates a substantial interconnectedness or co-occurrence with other topics within the cluster. Cluster 2 focuses on "sustainability" which stands out as an area of significant importance and strong interconnectedness with a high link strength of 2,841 despite a citation count of 212. This emphasizes the substantial association and extensive interconnection of sustainability with various other subjects within the cluster. Similarly, in Cluster 3, "science education" emerges as a highly focused and strongly interconnected subject area, showcasing a link

strength of 2,786 signifying its pivotal role and deep interlinkages within educational psychology, science education, and related domains. Cluster 4 highlights a focus on higher education-related topics, such as "review of educational research," "higher education," and "computers and education" suggesting a focus on innovation and enhancement within educational settings. Lastly, within Cluster 5, "computers and education" stands out as the most prevalent and extensively linked focus, evidenced by its impressive link strength 4,954, indicating a robust and profoundly interconnected with various other topics and discussions within the cluster.

Table 2

Keywords with the Strongest Citation Bursts in Discipline Categories

Cluster	Source	No. of Citations	Total link strength
1	21st century skills: learning for life in our time	28	382
	Assessment and evaluation in higher education	22	426
	Assessment and teaching of 21st century skills	41	565
	Chemistry education research and practice	22	591
	Creative education	28	366
	Education and information technologies	71	1457
	Education sciences	68	1458
	Educational leadership	33	418
	Educational research and reviews	24	487
	Elementary education online	23	369
	English language teaching	31	410
	School science and mathematics	38	1044
	Science and technology education	26	589
	Teaching and teacher education	101	1976
	Technology and engineering teacher	20	515
	Theory into practice	34	676
	Thinking skills and creativity	137	2569

(continued)

Cluster	Source	No. of Citations	Total link strength
2	A review of research on project-based learning	22	195
	Computer education	80	983
	Computer human behaviour	30	356
	Education information technology	20	270
	Education psychology	30	288
	Education research	20	198
	Research methods in education	20	275
	Science education	23	263
	Sustainability	212	2841
	Teacher teaching education	24	345
	Technology trend	37	946
	Thinking skills and creativity	22	140
3	Contemporary educational psychology	43	1056
	Educational psychologist	99	2158
	Educational psychology	23	574
	Instructional science	63	1851
	Learning and individual differences	29	734
	Learning and instruction	45	1015
	Medical education	28	555
	Research in science education	63	1601
	Science	22	388
	Science education	107	2786
4	Assessment and evaluation in higher education	22	426
	Computers and education	45	1020
	Higher education	56	1082
	Improving schools	37	545
	Innovation in education and teaching international	22	466
	Review of educational research	69	1586
	Studies in higher education	49	904
	Teaching in higher education	20	393

(continued)

Cluster	Source	No. of Citations	Total link strength
5	Computers and education	222	4954
	Computers in human behaviour	129	3077
	Educational technology and society	49	1574
	Educational technology research and development	78	2390
	Interactive learning environments	62	1584
	Technology, pedagogy and education	20	556
	The internet and higher education	38	897

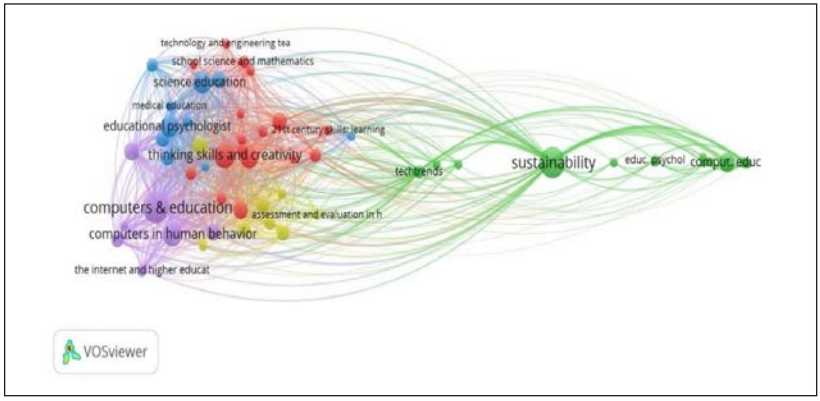
As illustrated in Figure 7, the VOSviewer's larger nodes, particularly within "computer & education" and "sustainability", indicate these subject areas' high prominence and significance within the dataset. This suggests that they are focal points with extensive connections and are more prevalent compared to other themes or subjects. The proximity and density of subject areas like "educational psychologist", "science education", "computers in human behaviour", and "thinking skills and creativity" around 'computer and education' indicate strong interconnections and frequent co-occurrences. These interconnections suggest shared discussions or thematic relationships between these subjects and "computer and education." The clustering implies thematic connections, such as educational technology intersecting with science education within the context of "computer and education." The dense clustering highlights how discussions or research around "computer and education" often involve or closely relate to specific subjects, emphasizing the interconnectedness and relevance of these subjects to the broader theme of "computer and education" within the dataset.

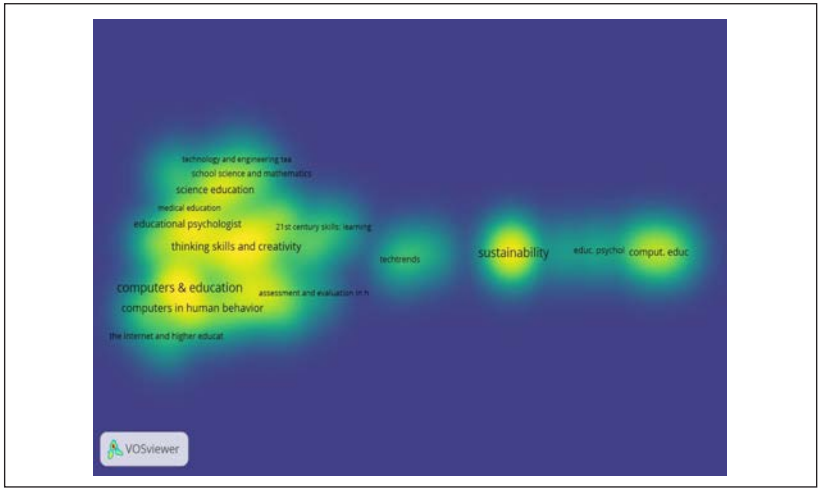
The symbiotic interplay between research themes, participating disciplines, and disciplinary development often underscores how various research themes and disciplines within a field complement and influence each other's growth and evolution. The growth and expansion within research themes and disciplines often parallel the development of human behaviour and address concerns related to student instruction and learning. As research themes expand and diversify, they often cater to emerging needs and challenges in

education, technology, and psychology. For instance, advancements in educational technology might directly impact student learning behaviours or instructional methodologies. Likewise, evolving psychological research might shed light on effective teaching practices that cater to diverse learning styles or address behavioural challenges in educational settings. Therefore, the growth and evolution of research contribute significantly to the understanding and handling various facets of human behaviour and educational practices, fostering improved student instruction and learning experiences.

Figure 7

Network and Density Visualization Evolution Trends of the Subject Area (Centre for Science and Technology Studies, 2023)





Based on the table and VOSviewer analysis, the intersection or overlap among subject areas within the literature on PjBL is significant (RQ5). Visualization tools, particularly VOSviewer, highlight dense clusters around key subjects like "computer & education" and "sustainability," indicating their extensive connections and prominence within the dataset. Additionally, strong thematic relationships and interconnections between subjects such as "educational psychology," "science education," and "thinking skills and creativity" around "computers and education" suggest a significant intersection or overlap among these subject areas. This finding suggests a significant intertwining or shared discussion among various subjects, highlighting a considerable portion of the literature focusing on PjBL and 21st-century skills.

Distribution of Institutions

A total of 160 institutions have published papers in this field. Among them, UM contributed the most with 26 documents, followed by UNY with 17 documents), UNS with 15 documents, UPI and UNJ with 14 documents each, UNNES with 9 documents, Helsingin Yliopisto with 8 documents, UNESA and Undiksha with 7 documents, UKM, UPSI, and Untirta with 6 documents, HKU, KMUTT, TAU, NTNU, UNP, and UNM with 5 documents as seen in Figure 8. Co-authorship relationships were analyzed among institutions with at least four publications. The institutions with the highest total connection citations were UM (total citation = 35 with four documents), UNS (total citation = 18 with six documents), and UNNES (total citation = 3 with four documents).

UM (Universitas Negeri Malang) leads with the highest number of documents (26), followed by UNY (Universitas Negeri Yogyakarta) with 17 documents, and UNS (Universitas Sebelas Maret) with 15 documents, among others contributing varying numbers. The analysis explores co-authorship relationships among institutions with at least four publications, highlighting collaborative efforts. It identifies UM, UNY, and UNS as institutions with notable connections based on total citations and documents.

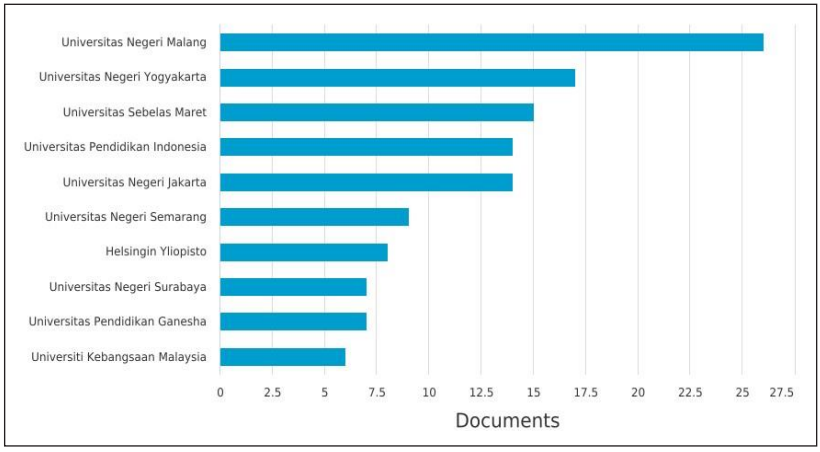
Another interesting observation from the data is the varying impact and influence of institutions, despite differences in the number of publications. UM, despite having fewer documents (4) than other institutions with higher publications, stands out with a notably higher total citation count (35). This indication suggests that UM's

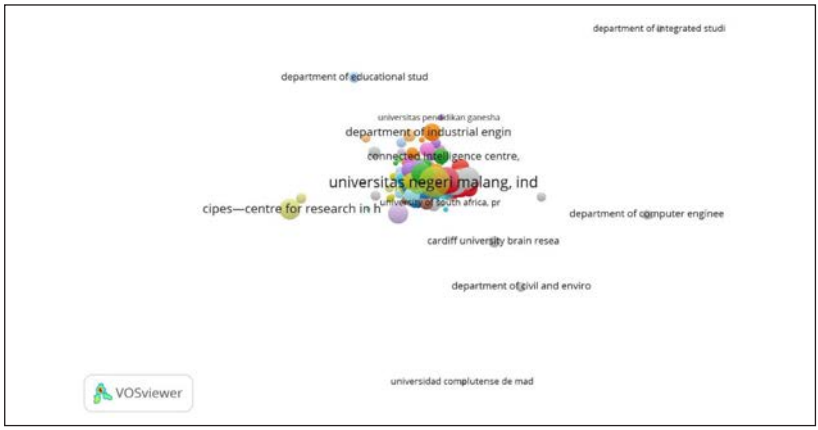
publications had a more significant impact or garnered higher recognition than some institutions with more documents. Analyzing co-authorship relationships among institutions with at least four publications highlights diverse collaboration patterns. Some institutions may have fewer publications but stronger connections or impact in terms of citations, emphasizing collaboration quality over quantity. The total citation count provides insights into how institutions' publications are acknowledged or cited within the field showcasing recognition and impact.

VOSviewer illustrates that Universitas Negeri Malang's identification as the largest node and the most densely connected environment signifies its prominent position and strong connections within the analyzed dataset (Figure 8). The node size suggests the significance or prevalence of Universitas Negeri Malang within the dataset. The dense environment around Universitas Negeri Malang, featuring institutions like Connected Intelligence Centre, Universitas South Africa, Department of Industrial Engineering, and Universitas Pendidikan Ganesha, indicates a closely interconnected network or thematic relationships among these institutions.

Figure 8

Top Ten Institutions with the Largest Number of Publications and Network Map of Co-Authorship Between Institutions with More Than Four Publications (Centre for Science and Technology Studies, 2023; Scopus, 2023c)





The clustering in Figure 8 suggests that these entities often share collaborative or thematic associations with Universitas Negeri Malang within the analyzed dataset. This suggests potential collaborations, shared discussions, or research interests between Universitas Negeri Malang and these associated institutions, highlighting their close interactions or thematic relevance within the dataset. The Distribution of Institutions analysis, notably emphasizing Universitas Negeri Malang as a pivotal node and its dense interconnectedness with associated institutions, directly addresses RQ6 regarding the distribution of published papers on PjBL and 21st-century skills among diverse institutions. The prominence of Universitas Negeri Malang as the largest node underscores its substantial contribution to published papers within this field. This analysis elucidates how published papers on PjBL and 21st-century skills are distributed through interconnected collaborations and shared interests within this scholarly domain, showcasing the intricate web of contributions among diverse institutions.

Analysis of Journals

A total of 500 papers are published across 156 journals. The analysis reveals the top five most popular journals for publishing papers on PjBL and 21st-century skills (Figure 9). Education Sciences leads with 32 published articles, followed closely by Sustainability Switzerland (29 articles), International Journal of Instruction (26 articles), Frontiers in Education (16 articles), and several other journals with 14 articles each. These figures indicate the publication frequency within each journal regarding the discussed themes. The most cited journals include Sustainability Switzerland with 182

citations, followed by the International Journal of Instruction (158 citations), Education Sciences (145 citations), International Journal of Emerging Technologies in Learning (115 citations), and Thinking Skills and Creativity (111 citations). This citation frequency indicates the impact and recognition these journals have received within the field, showcasing their influence based on the number of citations their published papers have garnered. The analysis of co-cited journals (146 journals co-cited at least 20 times) provides insights into the interconnectedness or relationships between journals within this domain.

The depiction in VOSviewer of a network map showcasing 146 journals co-cited in at least 20 publications (Figure 10) suggests an interconnectedness or strong co-occurrence among specific journals such as the Journal of Physics: Conference, Interdisciplinary Journal of Physics, Journal of Research in Science, International Journal of Science, Computers & Education, British Journal of Educational, Jurnal Pendidikan IPA Indonesia, and Educational Researcher, with significant nodes for the Journal of Physics. This suggests an interconnectedness or strong co-occurrence among these journals within the analyzed dataset. The density of these journals indicates that they share many citations or references among themselves and other related publications. This illustration suggests a close thematic or conceptual relationship, likely reflecting shared discussions, cross-referencing, or similar focuses among these journals within the domain of the analyzed subject area.

Figure 9

Top Five Most Popular Journals (Scopus, 2023f)

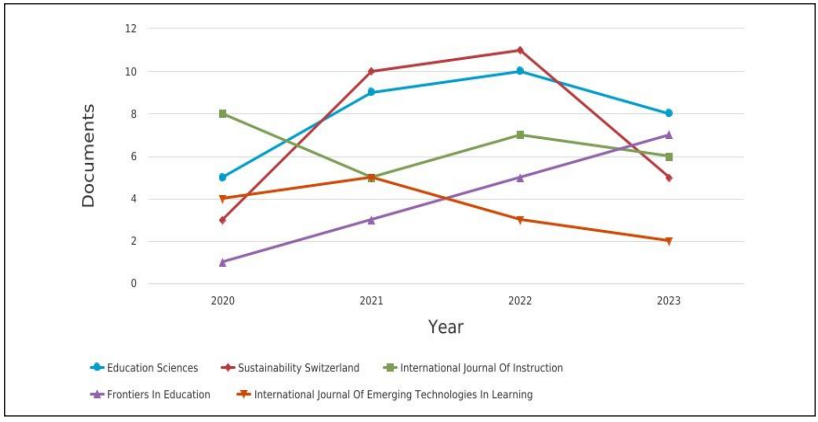


Figure 10

Network Map of Journals Co-Cited with At Least 20 Publications (Centre for Science and Technology Studies, 2023)

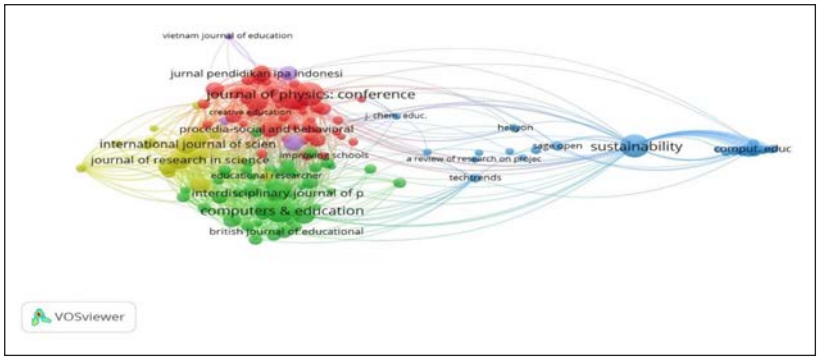


Table 3

The Top Ten Popular Journals and Cited Journals

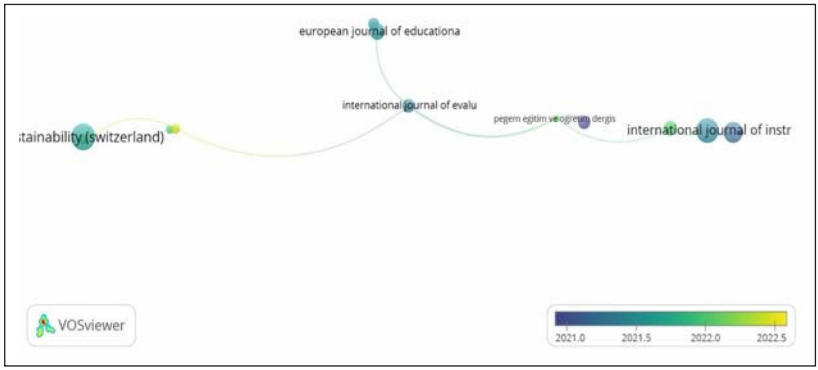
Rank	Journal	No. of Documents	No. of Citations	Total link strength
1	Sustainability Switzerland	29	182	1
2	International Journal of Instruction	26	158	2
3	Education Sciences	32	145	0
4	International Journal of Emerging Technologies in Learning	14	115	2
5	Thinking Skills and Creativity	6	111	0
6	European Journal of Educational Research	12	71	4
7	Jurnal Pendidikan IPA Indonesia	14	55	2
8	International Journal of Evaluation and Research in Education	14	47	6
9	Universal Journal of Educational Research	12	47	2
10	Cypriot Journal of Educational Sciences	11	36	3

Table 3 delineates the top ten popular and cited journals and draws several insights regarding journal popularity, citation impact, and total link strength. Sustainability Switzerland emerges as the most popular journal based on document count, with 29 articles, followed by Education Sciences (32 articles) and the International Journal of Instruction (26 articles). The table also highlights the citation impact of these journals. Sustainability Switzerland ranks third in citation count (182 citations), whereas the International Journal of Instruction leads in citations (158 citations), followed closely by Education Sciences (145 citations). The data suggests that while specific journals publish more documents, others might receive higher recognition within the scholarly community based on the citations their published works receive. The total link strength indicates the interconnectedness or co-occurrence of these journals within the analyzed dataset. Journals with higher link strengths, such as the European Journal of Educational Research (4), the International Journal of Evaluation and Research in Education (6), and the Cypriot Journal of Educational Sciences (3), indicate a more significant interconnectedness or reference patterns among their published articles within the dataset.

The Overlay Visualization in VOSviewer (Figure 11), highlights significant nodes around specific journals with the most citations, such as Sustainability Switzerland, European Journal of Education, International Journal of Evaluation and Research in Education, and International Journal of Instruction. This visualization indicates that these journals hold substantial influence or prominence within the dataset based on citation counts. The size and density of the nodes suggest that these journals have garnered many citations within the analyzed literature on PjBL and 21st-century skills. The clustering around these specific journals suggests that their articles are frequently cited together or are central references within this research domain. This suggests that these journals have a strong impact, influence, or centrality in shaping discussions or serving as primary sources of reference within this scholarly context.

Figure 11

Overlay Visualization Journal with the Most Citations (Centre for Science and Technology Studies, 2023)



While RQ7 primarily aims to identify journals with the highest prevalence or readership within the scope of PjBL and 21st-century skills, additional insights from the data, particularly from Figure 9 (top journals by document count), Figure 11 (top journals by citation count), and Table 3 (top ten journals by documents, citations, and total link strength), provide deeper insights beyond sheer readership. The figures and tables shed light on the frequency of publications in specific journals and reveal their citation impact and interconnectedness within the scholarly network. They provide a comprehensive understanding of journal prominence and influence within the field by presenting the total document count, citations, and link strength. This additional information extends beyond readership metrics to encompass the journals' impact on scholarly discourse and their relationships with other publications.

RQ7 primarily focuses on prevalence or readership, the supplementary data enriches the understanding by providing a holistic view of journal prominence, citation impact, and interconnectedness, offering researchers a more comprehensive perspective on the journals' significance within this research domain.

Analysis of Authors

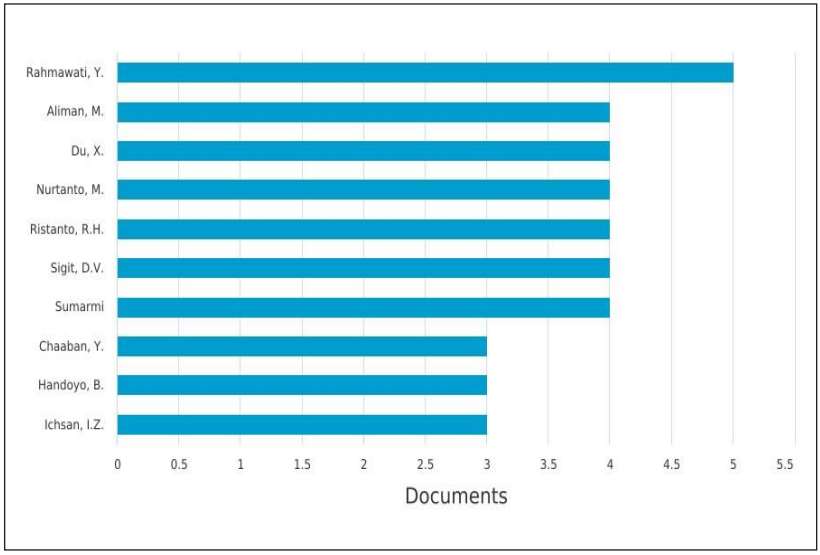
The distribution of authors presented in Figure 12 signifies the range of prolificacy among authors regarding the number of publications in the

given field. It illustrates that Rahmawati, Y. is the most prolific author with five publications, indicating a higher level of activity within this academic domain. Following closely behind are authors like Aliman, M., Du, X., Nurtanto, M., Ristanto, R. H., Sigit, D. V., and Sumarmi, each having four publications, suggesting a considerable level of contribution and engagement in this area of study. Meanwhile, the subsequent authors—Chaaban, Y., Handoyo, B., and Ichsan, I. Z.—also exhibit notable involvement but with slightly fewer publications, indicating their active participation but at a relatively lesser frequency than the top performers.

Publication quantity provides valuable insights into an author's productivity and engagement within a field. It helps gauge an author's level of activity and involvement in research. Tracking publication quantity assists in understanding an author's breadth of work, dedication to the field, and contribution to scholarly conversations. However, it is crucial to balance publication quantity with other factors like citation impact, quality of research, and influence within the academic community to understand an author's standing in their field.

Figure 12

Number of Author Publications (Scopus, 2023d)

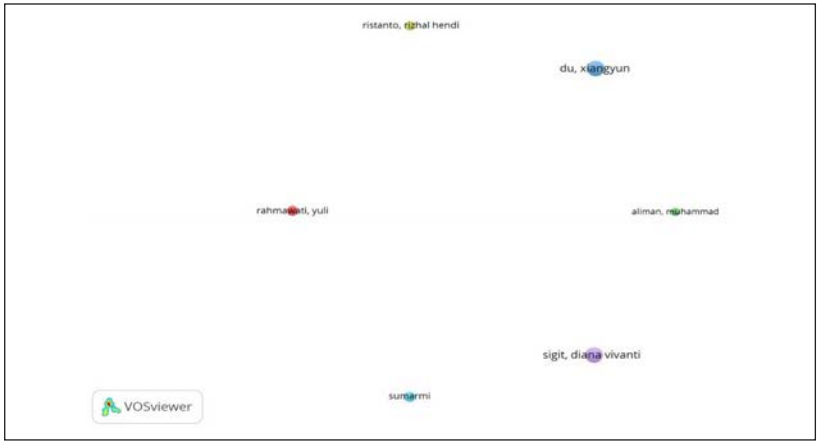


VOSviewer showcases nodes (Figure 13) of varying sizes for different authors based on total citations, implying their varying degrees of influence within the field. In this case, authors with the most significant node, Du, Xiangyun and Sigit, D. V., have accumulated more citations (57) compared to others. Rahmawati, Yuli appears to have less number of citations (22), followed by Sumarmi (26), Ristanto, Rizhal Hendi (23), Rahmawati, Yuli (22), and Aliman, Muhammad (16). Compared to the previous data on "The number of author publications" (Figure 12), Rahmawati Yuli has contributed a higher volume of published works, indicating a more prolific output. Meanwhile, Du, Xiangyun and Sigit, D. V. have fewer publications but are recognized for accumulating a notable number of citations, signifying a significant impact on the influence and recognition garnered through their research.

The total citations data provided by VOSviewer on Figure 13 aligns with the notion of balancing publication quantity with citation impact and influence within the academic community. While the nodes' size in VOSviewer represents the total citations accumulated by each author, indicating their level of recognition and influence based on citations, it is important to note that this metric alone might not encapsulate an author's entire academic standing. Authors with more citations are often seen as having more influence due to their research being frequently referenced or acknowledged.

Figure 13

Total citations from different authors in the field (Centre for Science and Technology Studies, 2023)

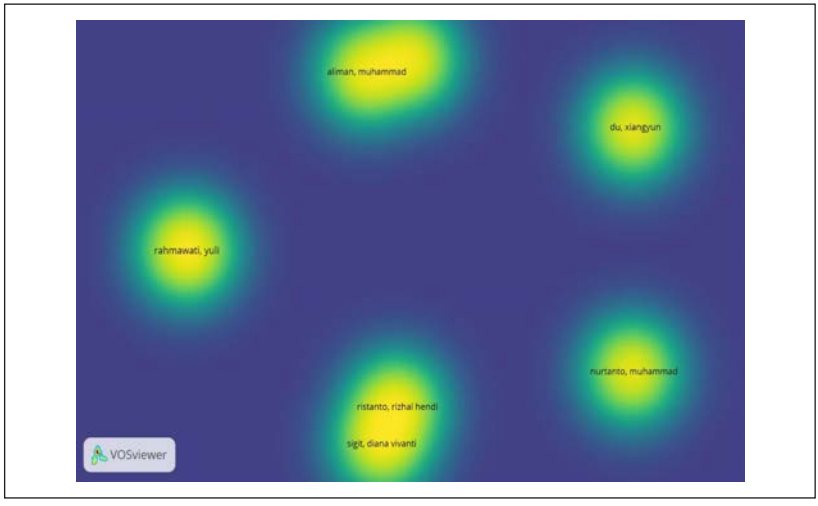


A comprehensive examination was conducted on a cohort of 1,542 writers collaborating on more than four articles. The network diagram (refer to Figure 14) illustrates the collaborative efforts of seven authors after eliminating non-connected writers. Aliman, Muhammad and Sumarmi exhibited the highest total link strength, each with a complete link strength of two occurrences. Following closely are Ristanto, Rizhal Hendi and Sigit, D. V., each with a total link strength of one occurrence. On the other hand, Du, Xiangyun, Nurtanto, Muhammad, and Rahmawati, Yuli did not exhibit any instances of link strength.

From the analysis of co-authorship, it is apparent that specific individuals have collaborative solid ties within this dataset featuring authors with more than four publications. Aliman, Muhammad and Sumarmi emerge as highly interconnected collaborators, indicating a consistent pattern of joint work. Ristanto, Rizhal Hendi and Sigit, D. V. follows closely, showing a moderate level of collaboration. However, Du, Xiangyun, Nurtanto, Muhammad, and Rahmawati, Yuli do not exhibit direct collaborative links within this dataset, despite their publication records. This analysis highlights the varying degrees of collaborative engagement among these authors in this dataset.

Figure 14

Density Visualization of Co-Authorship Between Authors with More Than Four Publications (Centre for Science and Technology Studies, 2023)



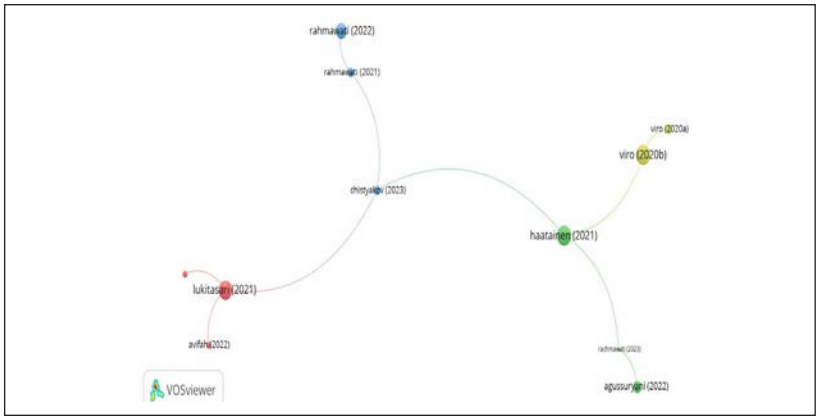
In exploring the landscape of PjBL and 21st-century skills, RQ8 probes into the identities of the most influential or highly cited authors in this field. In this examination, Du, Xiangyun and Sigit, D. V. emerge prominently due to their notable citation count of 57, positioning them as pivotal figures with substantial influence and recognition within the academic domain. In contrast, Rahmawati, Yuli leads in publication quantity with five papers, but her citation impact remains relatively lower at 22 citations, suggesting a need for increased visibility despite her extensive published works. The collaborative network analysis reveals varying degrees of collaboration among these authors, showcasing robust partnerships (Aliman, Muhammad, Sumarmi, Ristanto, Rizhal Hendi, Sigit, D. V.) and fewer direct co-authorship links within this dataset (Du, Xiangyun., Nurtanto, Muhammad, and Rahmawati, Yuli).

Analysis of Citations and Co-citations

The visualization in VOSviewer depicts a network map of 500 documents with more than two citations (Figure 15). The size of the nodes represents the frequency of citations received by each document. Larger nodes such as “Rahmawati (2022),” “Haatainen (2021),” “Viro (2020b),” and “Lukitasari (2021)” indicate that these documents have accumulated a higher number of citations, suggesting their significant impact or recognition within the analyzed dataset. Conversely, smaller nodes such as “Rahmawati (2021),” “Chistyakov (2023),” “Viro (2020a),” “Rachmawati (2023),” and “Avifah (2022)” have garnered fewer citations, indicating relatively lesser influence compared to the larger nodes. This network map visually represents the varying degrees of impact or citation frequencies among these documents within the dataset.

Figure 15

*Network Map of Citation Analysis of Documents with More Than Two Citations (*Centre for Science and Technology Studies, 2023)



The 32 references that exhibited co-citation in more than 20 citations were analyzed, as depicted in Figure 16. The significant shadows or clusters around authors like Trilling B., Fadel C., Kokotsaki D., Menzies V., and Bell S. on the "Density Visualization Map" suggest that these authors have a substantial impact or centrality within the discourse on PjBL. Their works or contributions have likely been highly cited and frequently referenced within the literature, indicating their influential role in shaping discussions, theories, or methodologies related to PjBL. These clusters suggest that their research has formed a core or significant component of the scholarly discourse in this field, indicating their prominent standing within the academic community focusing on PjBL.

Figure 16

Density Visualization Map of Co-Citation Analysis of References with More Than 20 Citations (Centre for Science and Technology Studies, 2023)

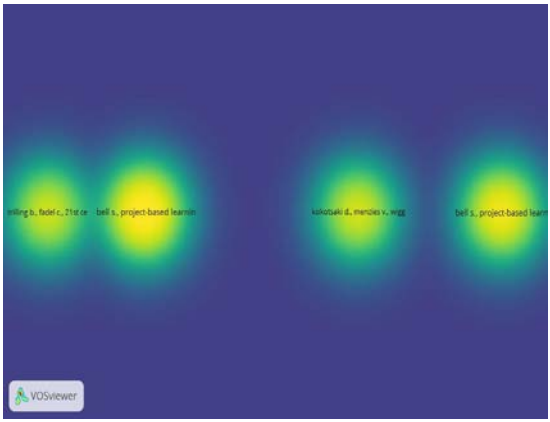


Table 4 shows a diversity of sources represented among the most highly cited publications in the field of PjBL and 21st-century skills. The sources include various journals such as the International Journal of Educational Research, Computers and Education: Artificial Intelligence, Computers and Education, Thinking Skills and Creativity, International Journal of Emerging Technologies in Learning, as well as others like the American Educational Research Journal and Education and Information Technologies. This variety of sources suggests that impactful contributions to this field are distributed across multiple journals and publication platforms, indicating a dispersed distribution of highly cited works rather than a concentrated trend in a single publication source.

While a singular pattern may be expected from the top-cited sources in Table 4, a trend emerges in the diversity of journals and publication platforms among the highly cited documents. Rather than being confined to a few select journals, the most cited works span various sources, suggesting that impactful research in PjBL and 21st-century skills are distributed across multiple publications. This diversification might indicate this field's broad interest and interdisciplinary nature, with valuable contributions arising from various academic sources rather than being centralized in a few key publications.

Table 4

Top 12 Citations Analysis of Publications in This Field

Rank	Title	First Author	Source	Publication Year	No. of Citations
1	A review of project-based learning in higher education: Student outcomes and measures	Guo P.	International Journal of Educational Research	2020	237
2	Conceptualizing AI literacy: An exploratory review	Ng D. T. K.	Computers and Education: Artificial Intelligence	2021	74
3	Towards a generalized competency model of collaborative problem solving	Sun C.	Computers and Education	2020	51
4	Developing critical thinking, collective creativity skills and problem solving through playful design jams	Tang T.	Thinking Skills and Creativity	2020	40
5	Effectiveness of augmented reality in online distance learning at the time of the COVID-19 pandemic	Eldokhny A. A.	International Journal of Emerging Technologies in Learning	2021	37
6	Active learning engagement in teacher preparation programmes - A comparative study from Qatar, Lebanon and China	Du X.	Asia Pacific Journal of Education	2020	31
7	Thai undergraduate science, technology, engineering, arts, and math (STEAM) creative thinking and innovation skill development: A conceptual model using a digital virtual classroom learning environment	Wannapiroon N.	Education and Information Technologies	2022	30

(continued)

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Rank	Title	First Author	Source	Publication Year	No. of Citations
8	Digital competence assessment methods in higher education: A systematic literature review	Sillat L. H.	Education Sciences	2021	29
9	Dynamics of reflective assessment and knowledge building for academically low-achieving students	Yang Y.	American Educational Research Journal	2020	28
10	Maker-centered project-based learning in inclusive classes: Supporting students' active participation with teacher-directed reflective discussions	Sormunen K.	International Journal of Science and Mathematics Education	2020	27
11	The influence of SRA programming on algorithmic thinking and self-efficacy using Lego robotics in two types of instruction	Fanchamps N. L. J. A.	International Journal of Technology and Design Education	2021	27
12	Design of learning media: Modeling & simulation of building thermal comfort optimization system in building physics course	Wati E. K.	Jurnal Pendidikan IPA Indonesia	2020	27

The analysis of citation and co-citation patterns among publications in PjBL and 21st-century skills reveals several noteworthy findings (RQ9). The visualization using VOSviewer identifies influential authors with significant centrality in project-based learning (refer to Figure 16). The network map (Figure 15) displays the frequency of citations received by various documents. Table 4 showcases a diversity of highly cited sources, spanning multiple journals including the International Journal of Educational Research, Computers and Education: Artificial Intelligence, Thinking Skills, Creativity, and others. This diversity implies that impactful contributions are dispersed across various journals rather than concentrated in specific sources.

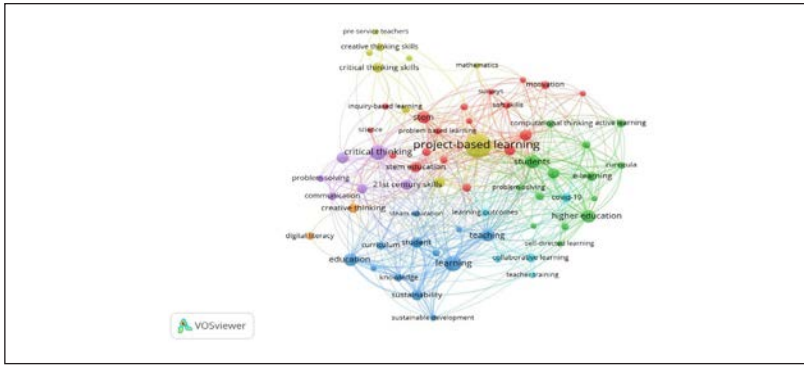
The Present Study Focuses on Doing a Co-occurrence Analysis of Keywords

A thorough analysis was conducted on 1,827 keywords, identified with a frequency of occurrence above five instances (refer to Figure 17A). The colours used in the overlay visualization depicted in Figure 17B indicate the average publication year of the selected keywords. Most keywords were distributed after 2021, primarily showing shades of green or yellow. The density visualization provided a clear representation of the specific keywords identified, along with their respective frequencies of occurrence (refer to Figure 17C).

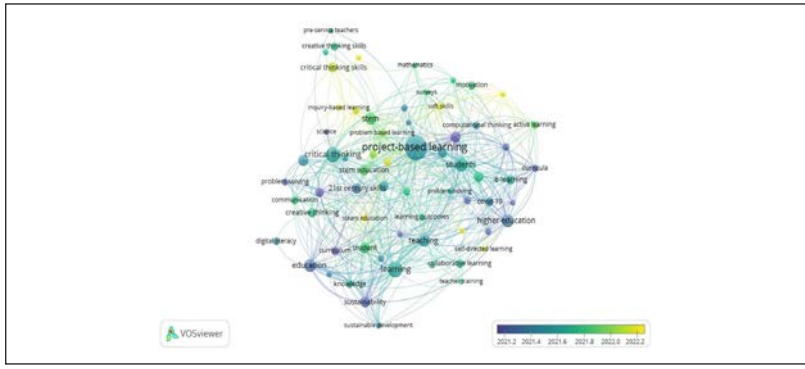
PjBL stands out as the most densely clustered keyword. This high density indicates that it is intricately connected or frequently co-occurs with other terms within the dataset. It is likely a central and highly discussed concept within the analyzed context. Learning emerges as a prominent term, forming a significant cluster. Though not as densely clustered as "project-based learning," its co-occurrence frequency suggests its relevance and interconnectedness with various other terms. Critical thinking and critical thinking skills also emerge as relatively dense keywords, indicating their significant association with other terms. These terms likely hold importance in discussions related to the dataset, with notable connections to various concepts or discussions. Higher education has a less dense representation than the others but still holds a considerable presence within the dataset. It might have slightly fewer connections or co-occurrences compared to the other keywords but remains relevant within the context.

Figure 17

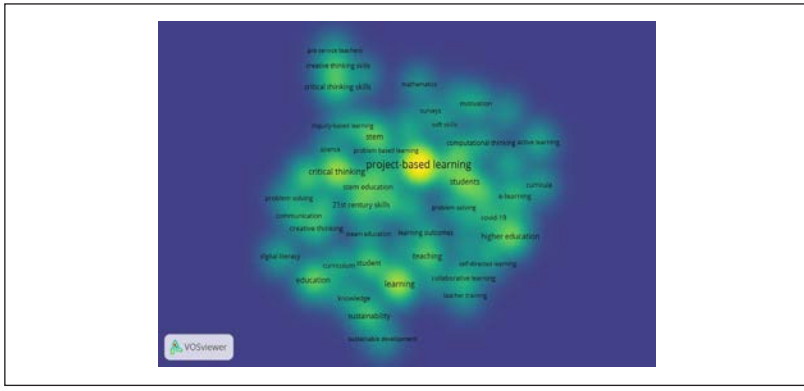
Co-occurrence Analysis of Keywords (Centre for Science and Technology Studies, 2023)



(A) Network visualization.



(B) Overlay visualization.



(C) Density visualization.

DISCUSSION

This study analyzes the bibliometric characteristics of 500 articles across various academic fields, utilizing a citation index to explore the global research landscape on PjBL and 21st-century skills. The analysis reveals a consistent upward trajectory in research output over the past three years, delivering crucial insights beneficial to scholars, policymakers, and educators seeking objective references.

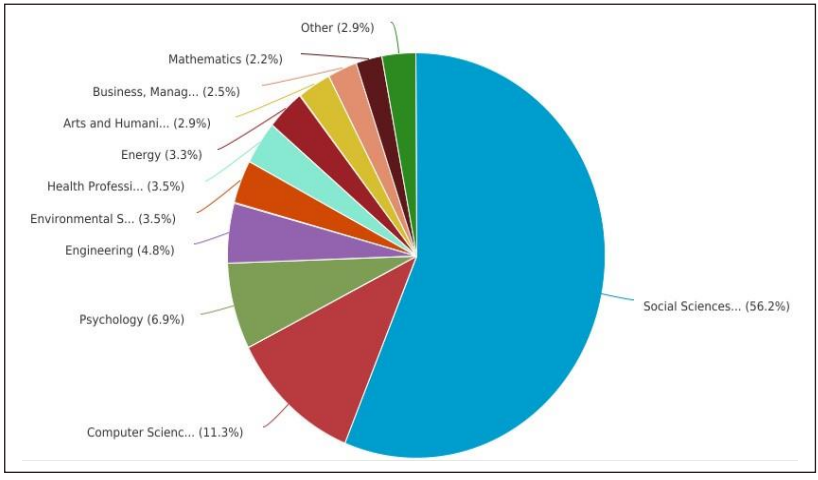
Indonesia and the United States contribute significantly to research efforts, demonstrating substantial collaboration across nations. Noteworthy partnerships for Indonesian research teams include collaborations with the United States, Malaysia, Australia, the United Kingdom, Sweden, and Taiwan. This partnership highlights the interdependence of worldwide research networks and importance of adhering to established standards. The landscape is marked by distinguished institutions such as Universitas Negeri Malang, Universitas Negeri Yogyakarta, Universitas Sebelas Maret, Universitas Pendidikan Indonesia, Universitas Negeri Jakarta, Universitas Negeri Semarang, Helsingin Yliopisto, Universitas Negeri Surabaya, Universitas Pendidikan Ganesha, and Universiti Kebangsaan Malaysia, shaping the collaborative hub with a significant volume of published works.

This study emphasizes the intricate nature of the mapping process, highlighting the pivotal role of teamwork in achieving impactful research outcomes. Furthermore, it emphasizes the ongoing evolution of educational practices across diverse academic domains. The shift towards fostering necessitates a reevaluation of teaching methodologies. PjBL emerges as a prominent approach, focusing on nurturing creativity, problem-solving, teamwork, and adaptability. Although acknowledged for enhancing students' preparedness for future careers, further research is needed to elucidate the precise mechanisms supporting learning within the PjBL framework (Pan et al., 2021). Diverging from conventional educational paradigms, PjBL redefines the educator's role as a facilitator, fostering active student engagement, collaboration, and experiential learning, culminating in tangible project outcomes. This pedagogical shift entails structured instruction, encouraging students to engage in in-depth investigative methods, thereby cultivating essential skills applicable in contemporary settings (Pan et al., 2019).

PjBL research extends beyond education-centric journals, permeating various academic disciplines, including social sciences, computer science, psychology, and engineering (refer to Figure 18). This indicates its multidisciplinary relevance and its integration into varied academic realms beyond the confines of traditional education-focused publications. Social science stands out as the most extensively researched or published subject area, constituting 56.2 percent of the total documents, followed by computer science (11.3%), psychology (6.9%) and engineering (4.8%). The interdisciplinary nature aligns with prior studies by Ghosheh Wahbeh et al. (2021) and Huang et al. (2023), underscoring the multifaceted and interconnected nature of PjBL across diverse fields (Ghosheh Wahbeh et al., 2021; Huang et al., 2023).

Figure 18

Percentage of Documents by Subject Area (Scopus, 2023g)



Student outcomes and measurements are becoming increasingly important in education, particularly regarding creative thinking, problem-solving with others, and critical thinking. This aligns with the growing recognition that PjBL effectively enhances critical skills across many academic fields (Sun et al., 2020; Tang et al., 2020). Authors with a high number of citations, such as Yuli R, X Du, and D. V. Sigit, significantly influence the direction of research. The study on teachers' readiness for implementing Project-Based Learning (PjBL) in Qatar is particularly noteworthy, as it has garnered substantial attention

and acknowledgment as a seminal work (Du & Chaaban, 2020). The study highlights the challenges in teacher readiness during the early transition stages and emphasizes the need for clear communication and assistance to ensure the successful implementation of PjBL. An examination of keywords uncovers a wide range of focuses in PjBL research, including computer-aided teaching, artificial intelligence, inquiry-based learning, blended learning, and STEM or STEAM education. This diversification of instructional methodologies aligns with the goal of enhancing active and constructive learning experiences, thereby contributing to educational advancement.

PjBL is a comprehensive technique within teacher education aimed at fostering and enhancing educators' self-efficacy, aligning with the overall imperative for educational institutions to equip pre-service teachers with the necessary skills and abilities for the 21st century. Systematic assistance and professional growth programs are crucial for ensuring teacher readiness and fostering favourable attitudes towards PjBL (Martinez, 2022). This work acknowledges the contributions of authors such as Ghosheh Wahbeh (2021) and Huang (2023), highlighting the interdisciplinary nature of PjBL research. The incorporation of computers in education is a notable subject of investigation, underscoring the interconnectedness of various academic fields and emphasizing the significance of integrating PjBL approaches. Ultimately, this thorough examination of PjBL and research on 21st-century skills provides a detailed understanding of international research patterns and partnerships. The high citation rates of its publications, the influence of its authors, and its applicability in interdisciplinary fields highlight the significance of PjBL in shaping educational practices. The study advocates the need for ongoing research to refine methodology and explore new trends, recognizing the ever-evolving nature of education.

Researchers acknowledge the importance of prior influential studies in education and emphasize their role in shaping educational practices. Bibliometric analyses should include these crucial studies as critical sources, providing context within the broader field of educational literature. The papers referenced in this study have received numerous citations and are significant in educational research. The authors have included these studies to enrich our understanding of PjBL and 21st-century skills within the specified time frame. However, this study is subject to inherent constraints. Firstly, it is important to acknowledge that bibliometric data is subject to temporal variations, potentially leading to different interpretations and conclusions over

time. Secondly, bibliometric analysis serves as a supplementary tool, and therefore, outcomes may deviate from real-world study settings. Additionally, the literature search was confined to Scopus databases, introducing a selection bias in the findings. Furthermore, by limiting the search terms to "project-based learning" and "21st-century skills," certain publications may have been overlooked.

CONCLUSION

This study provides a comprehensive examination of research outcomes and critical perspectives on PjBL and 21st-century skills on a global scale. The research on PjBL and its correlation with the development of 21st-century skills has exhibited steady growth in recent decades. Indonesia emerges as the most prolific nation, contributing to approximately 31% of scholarly papers, with UM standing out as the foremost academic institution in the country. Education Sciences is widely regarded as the preeminent scholarly journal in this field. Furthermore, establishing collaborative research projects between institutions in developing nations and their counterparts in affluent countries is imperative.

Beyond national and institutional borders, fostering collaborative research endeavours between developing and developed nations is essential. Such alliances promise to foster diverse perspectives, accelerate innovation, and drive the evolution of educational practices on a global scale. Emphasizing collaborative initiatives in this domain holds the potential to advance research and significantly contribute to the progressive development of educational methodologies and the cultivation of critical learners worldwide.

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