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Exploring Two Decades of Indigenous Knowledge Integration in Science Education: A Bibliometric and Systematic Literature Review

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Abstract: Indigenous Knowledge (IK) is an important factor in scientific knowledge in education globally. However, IK research is treated as a type of unfounded knowledge that is considered not to provide scientific solutions. As a result, the purpose of this research is to provide insight into IK research and IK integration patterns in science education over the last two decades from 2004 to 2024. The articles consist of 274 articles from the Scopus databases. This study uses a combination of bibliometric analysis and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol to provide a comprehensive view of IK research in science education. Bibliometric data was collected using VOSviewer and Biblioshiny software to provide visualization of publication analysis, information, author collaboration, to understand geographical distribution, as well as research topic trends related to the integration of indigenous knowledge. A systematic literature review is conducted to explore the researches in the selected articles systematically in contributing to the understanding of culture-based science concepts and their relevance in scientific knowledge. The findings show a significant increase in publications related to this topic. In addition, the study also highlights the challenges of incorporating local cultural perspectives into formal science curricula and suggests policies that can support the further development of the integration of indigenous knowledge in science education. The results of the research provide valuable insights for future research trends; The results of the study further highlight opportunities to build research partnerships to strengthen policy making and implementation.

Keywords: Bibliometric, Indigenous knowledge, Science education, Systematic literature review.

Introduction

Each country has indigenous knowledge passed down through generations that is not possessed by other countries. (Parmin & Trisnowati, 2024). Indonesia is one of the countries that has diverse indigenous knowledge due to its various ethnicities, races, and cultures. This indigenous knowledge is threatened with extinction due to the impact of modernization on people's lifestyles. However, indigenous knowledge plays an important role in several sectors, one of which is education. (Durie, 2005; Koehler, 2017; Naidoo & Singh-Pillay, 2024; Nurfaizah et al., 2024). Indigenous Knowledge (IK) can balance between local community participation and the use of structured science (Howes & Chambers, 1979). The integration of indigenous knowledge into education has received increasing attention in recent decades. Education plays an important role in preserving indigenous knowledge as it will be used as learning materials tailored to the knowledge being studied. Knowledge developed by indigenous communities typically holds varying meanings across different academic disciplines. Broadly, it encompasses local environmental insights, traditional knowledge, indigenous technical practices, agricultural

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wisdom, and community-based knowledge (Sillitoe, 1998). This information is transmitted orally, through observation and practice, in a dynamic process customized to address the needs of particular groups.

Science education in Indonesia is very important for preserving indigenous knowledge, as the risk of its extinction is becoming increasingly concerning (Dewi et al., 2024). The significance of science education within this framework is underscored by its correlation with societal advancement and the apprehension regarding diminishing levels of achievement and participation in the field of science (Okafor, 2018). Although indigenous knowledge is rich and multifaceted, it is frequently overlooked in knowledge-creation spaces, where it is typically labeled with terms like "primitive," "backward," "savage," "rural," and "unscientific." (Ezeanya-Esiobu, 2019). One of the major obstacles in science education is students' perception of science subjects in high school, which are considered boring, uninteresting, and irrelevant (Köse & Çetin, 2024; Gerondio et al., 2023). The divergence between science education and students' everyday experiences and societal environment has been recognized as the primary cause of this perception gap (Childs et al., 2015). Efforts in science education are more relevant, requiring a creative curriculum and teaching methods that go beyond mere theory and conventional scientific facts. Innovation in science education initiatives, such as using "indigenous knowledge" to enhance science teaching methods, should be grounded on theory and data (Elvianasti et al., 2023).

The importance of IK in science education in schools has become a focus in the field of education in a country. However, there hasn't been enough emphasis on the value of the knowledge and abilities that are inherent in the interaction between humans and nature (Kightley et al., 2013). Furthermore, the contributions of indigenous and local communities in maintaining natural systems through the preservation of language, customs, and traditions have not been fully appreciated. Society recognizes the value of nature in enriching their relationships, knowledge, and understanding (Sangha et al., 2018). Teachers can create a more inclusive and thorough approach to scientific teaching in the classroom by fostering an environment that values and integrates IK (Parmin & Fibriana, 2019). This step not only encourages cognitive development and learning achievements of students but also equips them to face complex global challenges, such as climate change and biodiversity conservation. Thus, the role of IK becomes increasingly important in supporting innovative efforts in science education.

Research has consistently highlighted the strong link between human engagement with the natural environment and improved health outcomes, with particularly profound effects observed among indigenous communities. Studies also suggest that focusing on social and cultural elements of health, alongside a holistic view of well-being, can enhance our understanding of health disparities. This research examines the evolution of integrating indigenous knowledge into science education over the last twenty years, providing a comprehensive review and trend analysis of literature on incorporating local knowledge in science curricula. The study explores the potential impact of such practices on school programs and learning methods, including applications in fields like physics, chemistry, and biology. It centers on publications related to science education in schools within developing or emerging nations.

Materials and Methods

Study area

This research focuses on the integration of Indigenous Knowledge (IK) in the field of science education. The IK referred to includes local and traditional knowledge passed down through generations in indigenous communities, encompassing worldviews, cultural values, and understanding of nature closely related to the environment and daily life. This study will cover the areas of primary and secondary education, where the scientific concepts taught are often oriented towards modern science. The use of IK in science education is expected to provide relevant local context, making science learning more meaningful for students and appreciating local

cultural knowledge. This research includes developing and rapidly developing countries, especially in regions with significant indigenous populations. The focus is on the educational context where resources and teaching materials based on local culture are often not yet available. Thus, this research will contribute to the understanding of the challenges and opportunities of integrating Indigenous Knowledge (IK) in science education, as well as its impact on increasing student engagement and a better understanding of science from different cultural perspectives.

Procedures

Data Search Instruments-1

The study focuses on the integration of Indigenous Knowledge (IK) in science education. The research uses a systematic literature review (SLR) as a data search instrument, employing filtering stages in the research procedure adapted from (Rejeb et al., 2022) which can be described as follows:

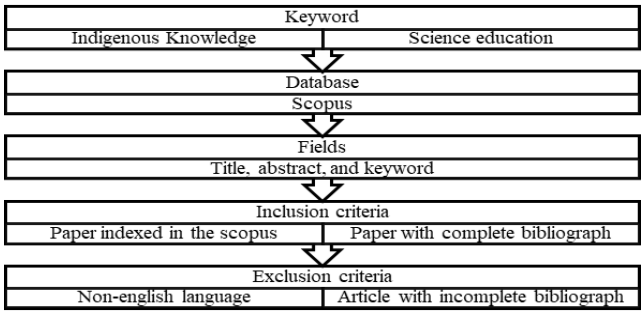

Figure 1. Research Procedure

Data Filtering-2

This study integrates bibliometric analysis, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) procedure, and a conventional review through full-text examination to yield thorough findings for this research. PRISMA asserts that a systematic review is a methodical approach to find, select, and critically assess pertinent research, in addition to gathering and analyzing data from the studies incorporated in the review. PRISMA is a procedure for executing systematic reviews, characterized by a four-stage flow diagram. The choice of PRISMA is attributed to its acknowledged comprehensiveness, its utilization across several disciplines, and its capacity to improve the reliability of review processes. The flowchart illustrating the systematic review process for publication selection for Scopus, based on PRISMA, is depicted in Figure 2.

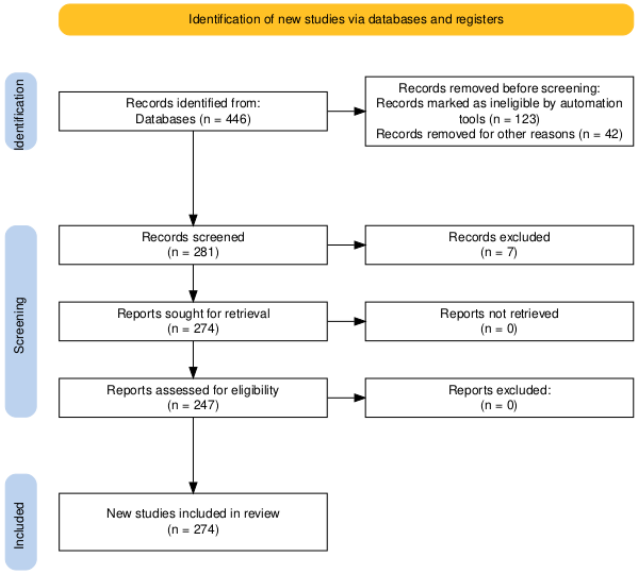

Figure 2. Flowchart PRISMA

Data Mapping using Bibliometrics-3

The next step involves analyzing the data using bibliometric literature to map the data through systematic and detailed methods. (Garza-Reyes, 2015). Bibliometric analysis methods are applied to identify publication trends, including journal types, research types, leading research institutions, countries of origin, citation patterns, as well as keywords and titles. (Szomszor et al., 2020). Bibliometric analysis is a study that describes and evaluates research work in the scientific literature through the use of various indicators (Broadus, 1987). Bibliometric analysis was chosen because it allows researchers to identify trending or developing topics in the research, as well as providing access to the latest research insights (Liu et al., 2022). There are five stages of bibliometric literature study methods according to Tranfield et al., (2003) and Setyaningsih et al., (2018) are as follows:

Figure 3. Bibliometrics Research Stages

1) Determine Search Keywords

The keywords used in searching for articles to align with the research objectives are the words "Indigenous Knowledge" OR "Local Wisdom"

AND "science" AND "education." These keywords must at least be present in the keywords, abstract, and title of the related articles. In September 2024, an article search was conducted from the Scopus database. Scopus, as one of the reference databases sources, was used to find reliable and high-quality articles for this research theme (Baas et al., 2020).

2) Initial search results

The search was conducted on "Journals" and "Proceedings," selecting only "Articles" as the type of paper, and the "year" was set for the last two decades, from 2004 to 2024. The first search yielded 446 articles, which were then filtered down to 274 articles that could be analyzed. The results are compiled in CSV format, with the information included in the CSV file consisting of the article name, title, abstract, keywords, affiliation, and finally references.

3) Refinement of Search Results

Relevant topics indexed in the Scopus database are selected first, with the aim of ensuring the sources come from "Journals" and "Proceedings." Core metadata updates are carried out simultaneously on the workbook saved in CSV file format, while continuing further data analysis..

4) Compiling the satistics of search results

Data collection is stored in CSV format. At the first level, the elements of the journal and proceeding themes and abstracts must comply with (Issue, volume, page, number, year, etc). Next, corrected by scientists to convey the necessary information if there are incomplete evidence findings. Evidence search is conducted so that topics can be grouped based on the year corresponding to the research publication source.

5) Data analysis

The final data will be analyzed bibliometrically by reviewing and visualizing the data on a bibliometric network to observe the exploration and trends of IK in science education. The analysis will be conducted using VOSviewer and Biblioshiny. VOSviewer is an interactive and effective tool for data visualization and analysis, capable of handling large amounts of data (van Eck & Waltman, 2010). VOSviewer can generate maps of authors, journals, or publications through co-citation networks. Additionally, VOSviewer can visualize keyword maps generated from collaborative networks. VOSviewer is also capable of producing publication networks, researcher diagrams, and representations of articles within the same group through the keyword mapping process based on co-citation networks (Dong et al., 2024).

Results and Discussion

The study results and commentary were derived from an analysis of the keywords "Indigenous Knowledge" OR "Local Wisdom" AND "science" AND "education". The research explores the application of IK integration in science education globally. Literature sources published in journals and proceedings indexed by Scopus from 2004-2024 in English. The type of document analyzed in this study is articles, with a total of 274 articles from 172 different sources. (journals, books, etc). Data shows that scientific publications on the integration of indigenous knowledge in science education have an average of 20.49 citations per document and include 12,135 references. The average growth rate in research or publications is 12.39% per year during the measured period. The researchers who have published articles relevant to the topic include 791 authors with 85 articles with single authors, resulting in a percentage of international co-authorship standing at 14.6%. Additionally, the results can be obtained from five perspectives described as follows: distribution of publications, co-authorship, co-occurrence, citation, and the impact of IK integration on science education.

Distribution of Publications

Articles published on the topic of IK from 2004-2024 can be reviewed using the biblioshiny software, which is part of the R-package, showing fluctuating development. The results can be seen in Figure 4 below, which shows the distribution of scientific article publications on the integration of IK in science education over the past two decades. Based on the image, it can be seen that the trend of article publications related to this topic has experienced significant fluctuations during the period from 2004 to 2024. At the beginning of the period, the number of publications was still

relatively low, with only 2-4 articles per year from 2004-2006. However, there was an increase in 2007, reaching 10 articles. In the following years, from 2008 to 2018, the number of publications fluctuated between 2-15 articles with an unstable condition. Next, the number of publications increased quite drastically, peaking from 2020 to 2022, with each year reaching 28, 23, and 24 articles, perhaps due to the influence of COVID-19, which considerably impacted public assemblies (Uddin et al., 2023). After that, publications have continued to increase up to now, with 31 articles available for the year 2024, but by the end of the year, this number is expected to rise.

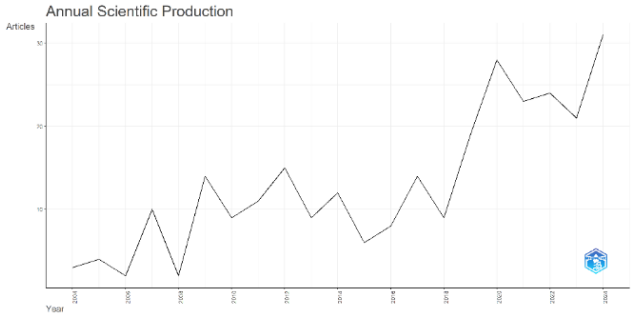

Figure 4. Distribution of publication

Analysis of Co-Word

Mapping the co-occurrence of significant or specific phrases identified in a particular article is based on co-word analysis focusing on keywords (Gorzeń-Mitka et al., 2020). Science mapping is a bibliometric visualization technique used to describe scientific domains. This method produces landscape maps to visualize scientific topics. VOSviewer displays keyword approach data in analyses referring to IK in science education, which is very diverse. This can be observed in Figure 5, which shows many clusters (14 clusters) of the visual network in relation to co-occurrence metadata.

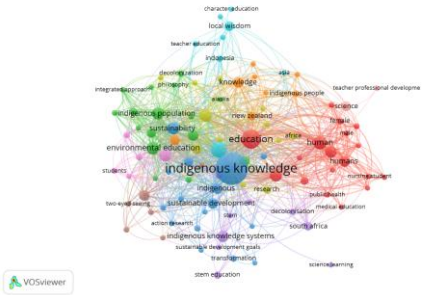

Figure 5. Network Visualization with IK in Science Education

The visualization shows a keyword network related to "indigenous knowledge" in science education and related fields, using VOSviewer. In the center of the network, the keyword "indigenous knowledge" is larger, indicating that this topic is a major focus in this dataset. This shows that many publications or research focus on the theme of traditional knowledge. There are several thematic clusters, such as sustainability and environmental education (green), sustainable development and STEM education (blue), public health and health education (red), as well as character education and the role of educators in traditional values (light blue), particularly in Indonesia. Keywords such as "South Africa," "New Zealand," and "Asia" indicate that this research is on a global scale. Overall, this network reflects the growing interest in integrating traditional knowledge into science education with various related issues, such as sustainability, public health, and the decolonization of education.

The visualization of research density related to IK in science education is also produced from VOSviewer analysis, as shown in Figure 6. The density visualization illustrates the intensity of research focus across various groups. This visualization can help identify research topics that have not yet been explored (Badeo & Duque, 2022). Brighter yellow colors indicate that a topic has been frequently or very frequently explored, while fainter or more muted colors suggest that the terms, keywords, or themes have been less researched, potentially leading to innovations and novelties in research related to IK in science education.

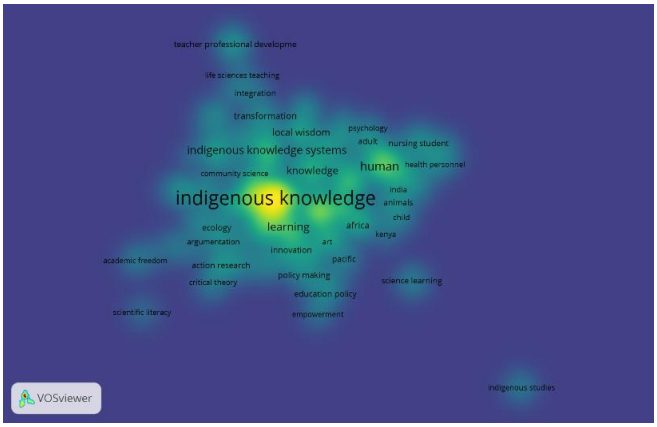

Figure 6. Density Visualization of IK in Science Education

Most Frequent Words

An important step in bibliometric analysis is identifying the keywords that most frequently appear in the analyzed literature. Keyword frequency analysis is one of the initial steps that can provide assistance. In addition to the global document, analysis can also be conducted by considering relevant and frequently used keywords in the writing of this article.

The results of the keyword documents analyzed using Bibloshiny are diagrammed in the form of a box plot, selecting the 10 most frequently appearing words in articles about indigenous knowledge in science education. It is very clear that the keyword "indigenous knowledge" has a very effective percentage with a total of 43%, followed by the keyword "education" with a total of 31%, the keyword "human" with 19%, the keyword "indigenous population" with 17%, and "knowledge" with 12%. More details can be seen in Table 1.

Table 1. Most Frequent Words

Words	Occurrences
Indigenous Knowledge	43
Education	31
Human	19
Indigenous Population	17
Article	16
Learning	15
Traditional Knowledge	15
Curriculum	14
Canada	12
Knowledge	12

Analysis of Co-authorship

The results of co-authorship metadata can be seen from the connections between authors and the countries of origin of the authors. This data visualization is obtained from its network and the overlay network visualization that can be seen in figures 7 and 8.

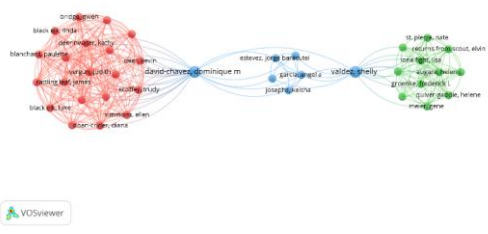

Figure 7. Network Visualization Co-Authorship (Authors)

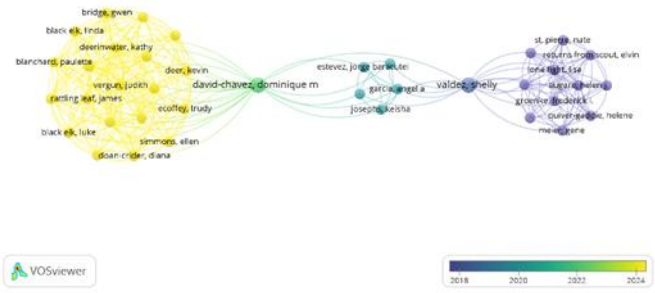

Figure 8. Overlay Visualization Co-Authorship (Authors)

Based on the data from image 7, it can be analyzed that there are three clusters of authors consisting of many authors with interconnected networks, meaning that each author has a relationship with one another. In addition, in Figure 8, it can be observed that changes occur in the author every year. It means the more yellow the name cluster is, the more recent the research was conducted. However, the metadata results above show the name of the blue cluster, meaning that the research has been underdeveloped for a long time. There are several clusters of authors that are interconnected, indicating collaboration among them. The group "deer, kevin", "deerwater, kathy", "vergun, judith", and "rattling leaf, james" seems to be working closely together. Meanwhile, "david-chavez, dominique m" serves as the main liaison between those clusters. On the other hand, some authors like "bridge, gwen," "black elk, linda," and "doan-cridge, diana" are separated from the main group, indicating a possible lack of interaction with other authors. There are also more independent clusters, connected with "st. pierre, nate," "returns from scout, elvin," and others. Overall, this visualization depicts complex connection patterns among the authors, with "david-chavez, dominique m" playing a central role as the main connector. A more in-depth analysis is needed to understand the dynamics of collaboration and the structure of the involved writing community.

The results of the bibliometric analysis are also presented in the figure showing the countries that contributed to producing research on IK in science education. This data visualization is viewed from

network visualization and overlay visualization, which can be seen in figures 9 and 10.

Figure 9. Network Visuslization Co-Authorship (Country)

Figure 10. Overlay Visuslization Co-Authorship (Country)

Based on the visualization of co-authorship data, the United States appears to be a major collaboration hub with many connections to other countries such as the United Kingdom, Canada, and South Africa, indicating its dominant role in the international research network. South Africa shows strong relations with Nigeria and several European countries such as Italy and Norway. Canada has close ties with the US and several Asian countries such as Taiwan and Indonesia. Indonesia and Taiwan especially collaborate with North American countries like Canada and the US. From the diagram with the color spectrum, it can be seen that collaboration increased between 2014 and 2022, with brighter colors indicating more recent collaborations. Each country shows diversity in international collaboration, indicating that research is multinational and interdisciplinary. Overall, this network demonstrates strong interconnectivity and interdependence in global academic research.

Analysis of Citation

The analysis of the number of citations of a scientific work is a fundamental aspect of the characteristics of that work. This analysis aims to conduct an analysis. Various scientific works and cited phenomena are used to establish the characteristics of bibliometric analysis methods. This citation analysis method is effective when applied in bibliometric research (Qiu et al., 2017). The network results on citation metadata can be seen in Figure 11, which shows a cluster of authors with high to low citations. This illustrates researchers who have a high interest in conducting research on the integration of IK in science education.

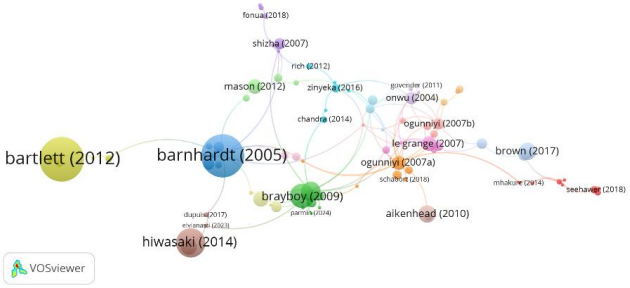

Figure 11. Network Visualization Citation

Based on figure 11, the largest cluster is (Bartlett et al., 2012) and (Barnhardt et al., 2005), then continued with the names of other researchers. In addition to the data obtained visually from VOSviewer, the data is also supported from the Biblioshiny software which can show the top 10 cited articles in IK research in science learning. It can be seen that the researcher whose work has been cited the most is Barlett C which was published in 2012 with 540 citations. Then followed by other researchers, more details can be seen in table 2.

Table 2. Top Ten Cited Article

No.	Publication year	Authors	Titles	Journal	Cites	Publisher
1	2012	Bartlett C	Two-Eyed Seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing	Journal of Environmental Studies and Sciences	540	Springer
2	2005	Barnhardt R	Indigenous Knowledge Systems and Alaska Native Ways of Knowing	Anthropology and Education Quarterly	513	Wiley Online Library
3	2007	Aikenhead GS	Indigenous knowledge and science revisited	Cultural Studies of Science Education	298	Springer
4	2014	Hiwasaki L	Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster	International Journal of Disaster	234	Elsevier

No.	Publication year	Authors	Titles	Journal	Cites	Publisher
			risk reduction and climate change adaptation in coastal and small island communities	Risk Reduction		
5	2009	Brayboy BMJ	Indigenous knowledges and the story of the bean	Harvard Educational Review	163	Harvard Educational Review
6	2007	Chinn PWU	Decolonizing methodologies and indigenous knowledge: The role of culture, place and personal experience in professional development	Journal of Research in Science Teaching	116	Wiley Online Library
7	2020	Zidny R	A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability	Science and Education	107	Springer
8	2017	Brown JC	A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning	Journal of Research in Science Teaching	86	Wiley Online Library
9	2005	Riggs EM	Field-based education and indigenous knowledge: Essential components of geoscience education for Native American communities	Science Education	86	Wiley Online Library
10	2010	Aikenhead GS	An emerging decolonizing science education in Canada	Canadian Journal of Science, Mathematics and Technology Education	84	Taylor & Francis

Discussion

Based on the systematic literature review and bibliometric analysis conducted, research on IK in science education has experienced significant development during the period 2004-2024. This shows that interest and attention towards the topic of integrating indigenous knowledge into science education have been increasing over the past two decades. Analysis of the keyword mapping shows several thematic clusters, including sustainability, public health, and STEM education. This indicates that IK is applied in various fields related to environmental issues, culture, and the decolonization of education. Many clusters are emerging that may continue to develop, meaning that future researchers can relate IK to science education in more detail. Collaboration between authors and countries such as the United States, which serves as a major hub for research collaboration with significant connections to other countries like the United Kingdom, Canada, and South Africa. Developing countries like Indonesia also contribute through collaboration with North American countries. This indicates that research related to the integration of IK in science education is still a trend and can continue to be explored and developed in more detail and broadly.

Several studies highlight the importance of indigenous knowledge (IK) in science education, one of which is in Zimbabwe, particularly in teaching food preservation. This study found that IK can promote community food security and suggests integrating IK into the curriculum to make learning more relevant to the local context. (Hlilokela et al., 2024). There are several types of IK that can be integrated into science learning according to several studies, including: 1) Traditional Food (local methods used by communities to preserve food, such as drying, fermentation, or smoking); 2) Utilization of local resources (using materials available in the surroundings for experiments or practical projects); 3) Local ecological knowledge (an understanding of local plants and animals, can also be utilized in ecosystem or biological studies). Integrating this IK allows students to understand science in a context that is more relevant to their daily lives (Aikenhead & Ogawa, 2007; Novitasari et al., 2017; Zidny et al., 2020 Saputri, A & Desstya, 2023).

The integration *of Indigenous Knowledge* (IK) or Traditional Knowledge in science learning has a significant impact in various aspects, ranging from

increasing student involvement, strengthening conceptual understanding, to educational inclusivity. In research Zidny et al., (2020), it was found that the application of IK fosters a sense of ownership and relevance to the material studied, thereby increasing students' motivation to actively participate in the learning process. In addition, IK allows students to understand science concepts in a local context that is more applicable and relevant to daily life. Study by Aikenhead & Elliott (2010) demonstrate that the use of local knowledge about ecosystems and biodiversity helps students relate ecological and biological concepts to the surrounding environment, thereby fostering a better understanding of sustainability and conservation. IK integration also plays a role in bridging the educational gap for students from indigenous or cultural minority backgrounds, by giving them recognition and appreciation. Brown (2017) noted that a responsive approach to local culture improves students' academic achievement and confidence, strengthening inclusivity in science education. In addition, traditional knowledge of local ecosystems drives awareness of sustainability practices, as discussed by Hiwasaki et al., (2014), which mentioned that IK has proven to be effective in educating students about disaster adaptation and community-based environmental conservation.

This integration also develops students' critical thinking skills by introducing them to the differences between local knowledge and modern science. In research Chinn (2007), Students who study science in a cultural context have a more flexible understanding and are able to think critically by considering diverse perspectives, so they are ready to adapt in a multicultural world. On the other hand, IK also plays a role in strengthening students' cultural identity, helping them maintain local knowledge that is full of traditional values and hereditary practices. As explained by Bartlett et al., (2012), The integration of IK through science education can be a medium for the preservation of endangered local traditions.

The results of this study also show the importance of encouraging policies that support the integration of IK in the science education curriculum. This kind of policy can serve as a framework that ensures the recognition and preservation of local knowledge in education (Annisha, 2024). The implementation of this policy can strengthen the relevance of science education, especially in schools located in indigenous communities or areas with high cultural diversity. This also supports more inclusive and culturally responsive learning, potentially increasing student engagement and academic achievement. With insights from this research, future policy-making can be more responsive to the local cultures and values of each community. For example, through the integration of traditional methods in science education, students can learn about sustainability and environmental preservation in a way that is relevant to them. (Yazidi & Rijal, 2024).

Policies that support the integration of local wisdom also open opportunities to promote education that values local wisdom, which is very important in facing global challenges such as climate change and environmental crises (Baena-Navarro et al., 2024; Munisa et al., 2024). This study recommends policies that encourage the integration of local knowledge into the science curriculum as a step to preserve culture and traditional knowledge threatened by modernization. Such initiatives can also help students understand science in a context that is more relevant to their daily lives, especially in communities with strong traditional knowledge.

Conclusions

This research shows that sustainable development-based education (ESD) in pesantren can significantly shape the attitudes and behaviors of santri who are more concerned about the environment and responsive to climate change. Through the integration of sustainability values in the curriculum and practical programs such as waste management and reforestation, santri not only gain a deep understanding but are also actively involved in environmentally friendly practices. The results indicate a positive relationship between santri's knowledge and attitudes towards sustainability and their pro-environmental habits. The pesantren serves as a center for environmental education that links Islamic values with the responsibility of preserving

nature. Thus, the implementation of ESD in pesantren has the potential to form a generation of santri who have a strong religious understanding as well as high social and environmental awareness, and make a real contribution in dealing with the impacts of climate change.

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