Cogent Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oaed20

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To cite this article: M. Muchson, William W. Cobern & Muhammad Saefi (2024) The science education research trends (SERT) in Indonesian secondary schools: a systematic review and bibliometrics study, Cogent Education, 11:1, 2308407, DOI: 10.1080/2331186X.2024.2308407

To link to this article: https://doi.org/10.1080/2331186X.2024.2308407

Published online: 01 Feb 2024.

COGENT EDUCATION
2024, VOL. 11, NO. 1, 2308407
https://doi.org/10.1080/2331186X.2024.2308407

INTERNATIONAL & COMPARATIVE EDUCATION | REVIEW ARTICLE

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The science education research trends (SERT) in Indonesian secondary schools: a systematic review and bibliometrics study

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ABSTRACT

Indonesian researchers have published a substantial number of research articles on science education. However, there is no overarching sense of the science education research landscape in Indonesia. The purpose of this study was to provide such an overarching sense with respect to science education research focused on Indonesian secondary schools between 2000 and 2020. Systematic review and bibliometrics methods were used to analyse 287 papers retrieved from Scopus. The study found that the publications have drastically increased since 2017 with only a few of them published in leading science education journals. International collaborations among Indonesian science educators have included many countries, such as Malaysia, Japan, South Korea, the United Kingdom, Australia, Thailand, and Canada. The most common research topics are critical thinking skills, problem-based learning, cooperative learning, HOTS, learning tools, blended learning, creative thinking skills, project-based learning, misconceptions, and lesson study, mostly researched through quantitative rather than qualitative methods. These findings are important for Indonesian science educators to assess their progress and identify areas for improvement to have a greater impact on the community. In the international context, these findings provide critical knowledge for global academics as they initiate and build international networks and collaborations to advance science education globally.

ARTICLE HISTORY
Received 22 November 2023
Revised 7 January 2024
Accepted 17 January 2024

KEYWORDS
Science education research trends (SERT); Indonesian secondary schools; systematic reviews; bibliometrics

REVIEWING EDITOR
Lawrence Jun Zhang, Curriculum and Pedagogy, University of Auckland Faculty of Education and Social Work, Auckland, New Zealand

SUBJECTS
Curriculum Studies; Middle School Education; Secondary Education; Teachers & Teacher Education

Introduction

A Science education research trends (SERT) study is a type of research synthesis that uses secondary data, such as journal articles or graduate theses and dissertations, to provide a detailed and comprehensive account of primary themes reflecting essential aspects of scientific research in the field of science education, including productivity, collaboration, research topics, and citation impact (Belter, 2018; Tosun, 2022). This type of study establishes a cohesive body of knowledge that allows us to not only better understand the status of science education in the past and present, but also to foresee substantial advancements that will take place in the field in the future (Gil-Pérez, 1996; Zupic & Čater, 2015). Science educators need to comprehend SERT if they are to evaluate their current research foci and plan future research and development (Chang et al., 2010; T.-J. Lin et al., 2019; Tosun, 2022). Knowledge of SERT is particularly important for assisting novice researchers in identifying crucial research topics and relevant references to generate innovative ideas for their sustained academic careers (T.-J. Lin

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et al., 2019; Tosun, 2022). According to Chang et al. (2010), conducting SERT studies may help science instructors identify alternative methods to improve their classroom teaching practice and play a more effective role in the preparation of a scientifically literate generation. Furthermore, Tosun (2022) argued that the findings of SERT studies might empower educational policymakers to exert a strong influence on regulation in science education. Finally, Medina-Jerez (2016) acknowledged the significance of SERT studies in establishing indications of a country's development prospects and productivity in the education sector.

There have been SERT studies that strived to map significant features such as major contributing authors, institutions, collaborations, research topics, as well as research methods regarding science education research conducted in the international context. For examples, Lin et al. (2019) examined SERT in terms of the most contributing countries in publications, research types, research topics, the top highly cited papers in all papers published in JRST, IJSE, and SE periodically every five years from 1998 to 2017. Furthermore, Wang et al. (2023) investigated SERT from the aspects of the growth of publications and citations, prominent research groups and their collaboration networks, and highly influential literature, as well as the most significant research topics and their evolution within papers published between 2001 and 2020 in seven top journals, including JRST, IJSE, RISE, SE, SSE, S&E, and JBSE. SERT studies have also been undertaken in the context of specific regions. Medina-Jerez (2016), for example, studied the growth of science education research in Latin American countries between 1998 and 2015. Another example is a study by Sozbilir et al. (2012), which identified research topics, research methods, and data analysis procedures in all science education research papers authored by Turkish scholars.

The problem with the existing SERT studies is that they primarily focus on accomplishments of major contributing countries while failing to portray trends in a regional/specific country that potentially distinct from international perspectives. Furthermore, there are no SERT studies that focus on Indonesia. Thus, the purpose of the current study was to provide a SERT study specific to secondary science education in Indonesia between 2000 and 2020. We decided to narrow our focus to secondary science education because our initial review of the literature indicated that most of the published research papers in Indonesia dealt with secondary schools.

Conducting a SERT study in the Indonesian context is critical because the results of the study can be a valuable guide for Indonesian scholars evaluating their recent progress and provide recommendations on what research and development needs improvement in order to significantly impact the community. Furthermore, the study results may assist Indonesian educational policymakers in developing long-term initiatives as attempts to address major issues, especially in science classroom teaching practices. In the international context, the study findings will be essential knowledge for global academics as they initiate and build international networks and collaborations to advance science education globally. Science education is primarily a sort of international affairs involving the participation and contribution of multiple nations from all over the world. Professional organizations based in various countries, such as the National Association for Research in Science Teaching (NARST) in the United States, the European Science Education Research Association (ESERA), and the Australasian Science Education Research Association (ASERA), provide a mechanism for science educators to communicate about improving science teaching and learning by means of research throughout the world. However, it is also feasible that a single country has unique research features in the field of science education. A SERT study for a given environment, such as the current study, can help. In this regard, the study may eventually help international scholars value contextualized studies in science education from more diverse cultures. Our research questions are as follows: Regarding Indonesian secondary schools between 2000 and 2020:

1. What growth in science education research has taken place, as judged by publication numbers?
2. Who were the leading science education research authors and institutions as judged by publication and citation numbers?
3. What collaboration in science education research has taken place, as judged by co-author relationship?
4. How has interest in various research topics ebbed and flowed?

5. What were the most highly cited publications, as judged by citation numbers?
6. How has interest in various research methods ebbed and flowed?

Methods

Employing bibliometrics and systematic review method independently in SERT studies offers strengths and weaknesses. Although systematic reviews have limited coverage due to their reliance on human labour (Tosun, 2022), they are effective in identifying research methodologies used in sample papers. Bibliometrics, on the other hand, provides the benefit of automated text analysis (Wang et al., 2023), which can reduce many of the obstacles involved with human effort, despite the fact that this method cannot specify research methodology. Furthermore, using a single categorization system in a systematic review may result in the omission of several essential keywords that are not covered by that system, as well as the potential of arriving at different conclusions when analysing the same sample papers using a different system (Chang et al., 2010). Given these strengths and weaknesses, we incorporated both methods to address the research questions in the current study. Figure 1 provides an overview of our study design.

We developed the search string from relevant references, including: (1) a list of research topics identified in the study by Wang et al. (2023), (2) the NARST strands, and (3) a list of science education keywords in the book *The Language of Science Education: An Expanded Glossary of Key Terms and Concepts in Science Teaching and Learning* by McComas (2013). We retrieved sample papers from the Scopus database by employing the method of *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA), resulting in 287 final selected articles as illustrated in Figure 2. We selected papers that were exclusively published in Scopus-listed journals in order to make them accessible to the global science education community. Additionally, we made certain that these papers were entirely written in English so that science educators from all around the world could understand them.

Table 1 provides the details of analytical methods along with the corresponding tools we employed to address each of the research questions. To increase the internal validity of systematic review results, we applied an inter coding technique in which two researchers independently categorized the sample papers according to the determined categorization system and then met to establish intercoder agreement. In this study, the agreement between two inter-coders achieved 87% for the component of major research topics, 93% for the main research methods, and 87% for the sub research methods.

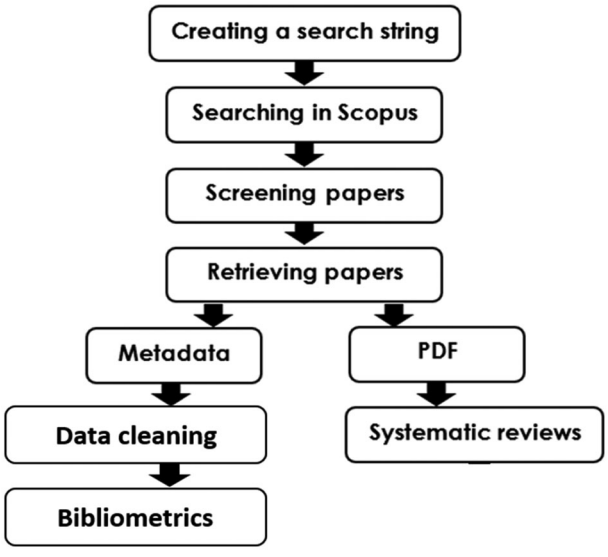

Figure 1. Study design including retrieval of sample papers and analytical methods.

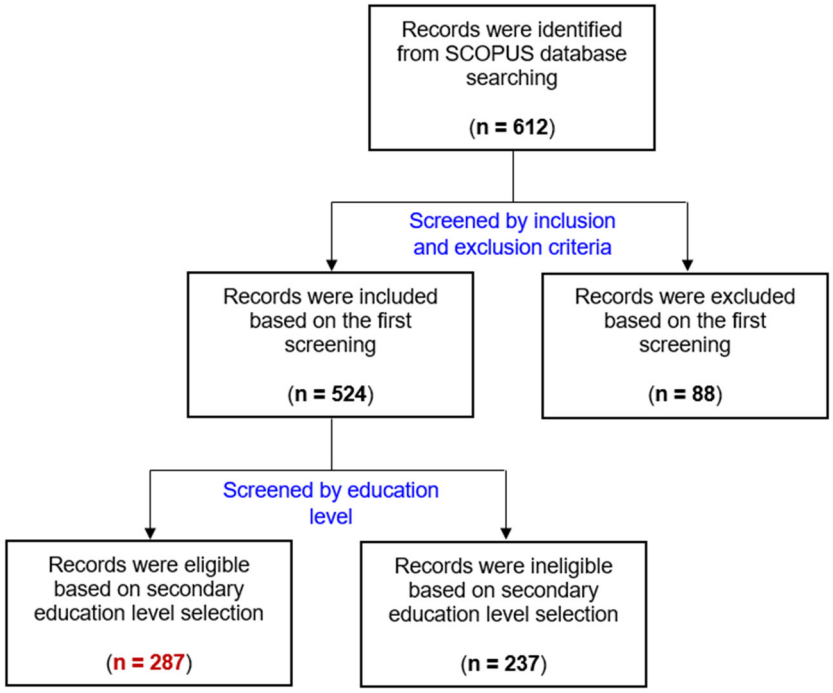

Figure 2. The PRISMA process of retrieval of sample papers.

Table 1. The details of analytical methods to address the corresponding research questions.

Research questions	Sub research questions	Methods	Tools
The growth of publication (RQ1)		Annual scientific production	Excel
Leading authors, institutions, and collaborations (RQ2)	Leading authors and their collaborations	Co-authorship with the unit of authors	VOSViewer
	Leading institutions and their collaborations	Co-authorship with the unit of affiliations	VOSViewer
International collaborations (RQ3)		Co-authorship with the unit of countries	VOSViewer
Highly cited publications (RQ5)		Co-citation with the unit of references	VOSViewer
Major research topics (RQ4)	Major research topics according to the NARST strands	Systematic review	Inter coding manually by following the categorization system of NARST strands applied by the CC Tsai research group
	Major research topics based on the most used keywords	Co-occurrence with the unit of all keywords	VOSViewer
Major research methods (RQ6)		Systematic reviews with content analysis	Inter coding manually by following the category of research methods described by McMillan (2006)

Results and discussion

The growth in publications

As apparent from Figure 3, no science education research focusing on Indonesian secondary schools was published prior to 2007. Between 2007 and 2015, the publication growth was slow, ranging only between one and four per year. However, beginning in 2016, there was a significant increase in publications, with an upward trend until 2020, when it reached 104 that year, the largest number during that time. Figure 4 shows that most of these publications were in Physics education, followed by Chemistry and Biology education, with the fewest in Integrated science education.

The sudden spike in Indonesian science education publications appears linked with the fact that the Ministry of Higher Education of Indonesia has since 2017 mandated international publication as one of the requirements for pursuing higher tenure positions for faculty in all institutions (The Ministry of Higher Education of Indonesia, 2017). In compliance with this policy, several graduate programs have

begun requiring students pursuing a doctoral degree to have international publications before defending their thesis or dissertation. Even though this regulation is more of a university preference than a national requirement, it seems to have a significant contribution to the rapid increase of international publications in science education authored by Indonesian scholars.

The Ministry of Higher Education in Indonesia specifically recommended that graduate students and faculty members publish their research papers in high impact factor international journals, as indicated by upper quartile (The Ministry of Higher Education of Indonesia, 2017). Journal quartile is the most

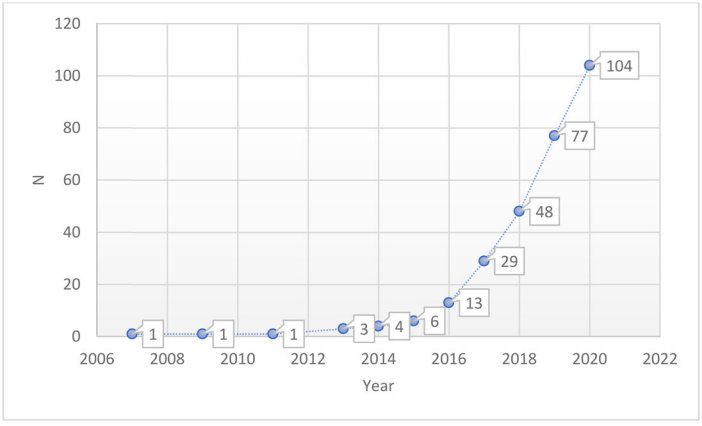

Figure 3. Annual scientific production of science education research focused on Indonesian secondary schools.

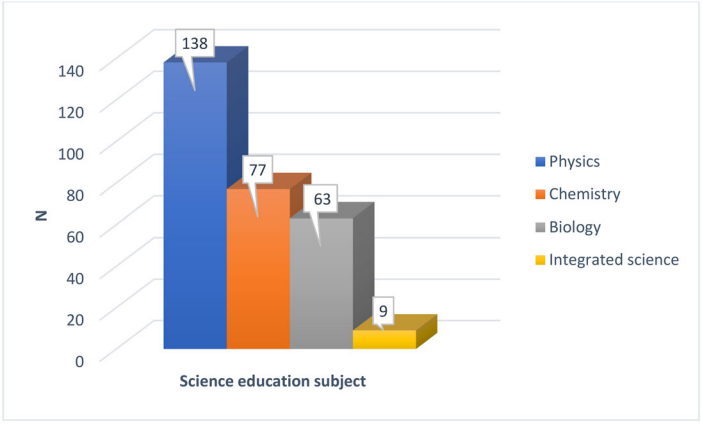

Figure 4. The distribution of sample papers in terms of science education subjects.

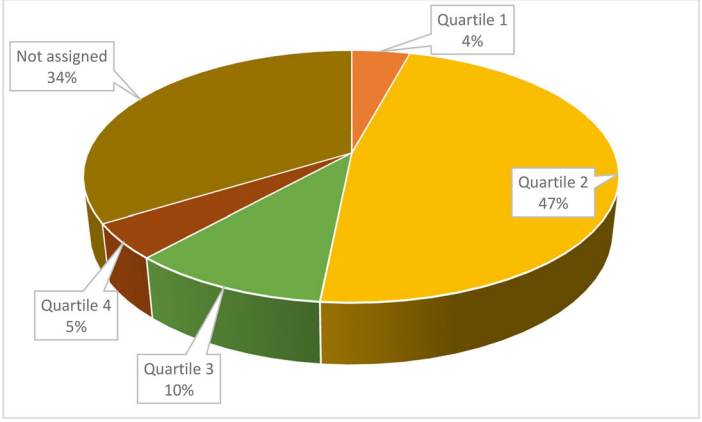

Figure 5. The distribution of sample papers in terms of the ranks of the journal sources.

prevalent measure used by journal level metrics, such as SCIMAGO Journal Rank (SJR) and Journal Citation Reports (JCR), to evaluate the quality and visibility of a journal in its field based on a set of indicators referred to as impact factor (García et al., 2012; W. Liu et al., 2016). Using such a metric system, a journal is categorized in the first quartile if it falls within the top 25% of the impact factor distribution for a certain subject area and in the fourth quartile if it falls within the bottom 25% of that distribution. As shown in Figure 5, the highest portion (47%) of the Indonesian research papers were published in the journals with the second quartile, while more than one-third (34%) were published in several journals that have not yet been assigned to any quartile. Appendix A lists the 52 journals that were identified as the sources for these publications, with Jurnal Pendidikan IPA Indonesia (Journal of Indonesian Science Education), an international journal based in one of Indonesian universities, publishing the most (59), followed by International Journal of Instructions in Turkey (38 papers) and Universal Journal of Educational Research in the United States (36 papers).

Only two of the total sample papers were published in the leading science education journal, International Journal of Science Education (IJSE), as indicated in Appendix A. The first is a paper by Handayani et al. (2019) that investigated science teachers' obstacles in building learning community through lesson study while the second is a paper by Agung and Schwartz (2007) that investigated students' understanding toward a certain chemistry concept. Another paper regarding science education in Indonesia that was published in IJSE is a study on students' overconfidence bias in biology exams by Rachmatullah and Ha (2019). This paper, however, was excluded from the samples since it did not include an author who had an affiliation with any Indonesian institution.

Aside from IJSE, none of the journals included in Appendix A are regarded as the top international journals in the field of science education (Taber, 2023). There are essentially a few research articles on science education that were written by Indonesian researchers and published in other prestigious journals like Journal of Research in Science Teaching (JRST) and Science & Education (S & E). For instance, Erman (2017) published an article in JRST examining variables influencing students' misconceptions when learning about covalent bonds, and Zidny et al. (2020) published an article in S & E reviewing how indigenous knowledge may enhance science education for sustainability. The first article was not included in the samples since it was conducted at the college level, whereas the present study focused on the secondary level. On the other hand, the second article was excluded since it adheres to a traditional narrative review style, which does not match the criteria for the sample papers included in the current study.

It is somewhat astounding that Indonesian science educators have only published a few papers in the top ranked science education journals IJSE, JRST, and S & E, and no papers have been published in the top ranked journals Research in Science Education (RSE), Studies in Science Education (SSE), or Science Education (SE). The issue seems to be connected to several challenges Indonesian authors have faced while trying to get their research papers published in reputable international journals. Writing manuscripts in appropriate academic English and structuring them in ideal rhetorical styles, according to some experts, appears to be the biggest barrier preventing Indonesian scholars from publishing their research articles in top international journals. (Arsyad & Adila, 2018; Hanami et al., 2023; Sukirman & Kabilan, 2023). Arsyad and Adila (2018) further argued that most of Indonesian researchers feel inadequate about the quality of their own research and publications, which hinders them from submitting their work to prestigious international journals. On the other hand, the insufficient incentive as an expected intrinsic rewards has been reported to be another factor in the low frequency of Indonesian publications in prestigious foreign journals. (Sahputri et al., 2022). All these challenges seem to be the more rational explanations for why many research papers from Indonesia are published in international conference proceedings, such as those produced by the IOP or AIP Publishing, rather than reputable international journals, as recorded in the SINTA, an Indonesian-based academic publication database.

The leading authors, institutions, and the collaborations

The leading authors and their collaborations

Co-authorship analysis identifies all contributors who have co-authored a paper(s), calculates the total number of publications and citations contributor, and assigns a group of contributors to a specific

Table 2. The leading authors' ranks based on the number of publications and citations.

Authors	Publications	Citations
Sulisworo, D.	13	96
Samsudin, A.	8	82
Zubaidah, S.	7	80
Ristanto, R. H.	6	43
Cahyana, U.	6	40
Rahmawati, Y.	6	29
Istiyono, E.	6	45
Susilo, H.	5	59
Saregar, A.	5	201
Wiyarsi, A.	5	27
Suprapto, N.	5	38
Batlolona, J. R.	4	89
Fratiwi, N.J.	4	47
Wardani, S.	4	61
Toifur m.	4	40

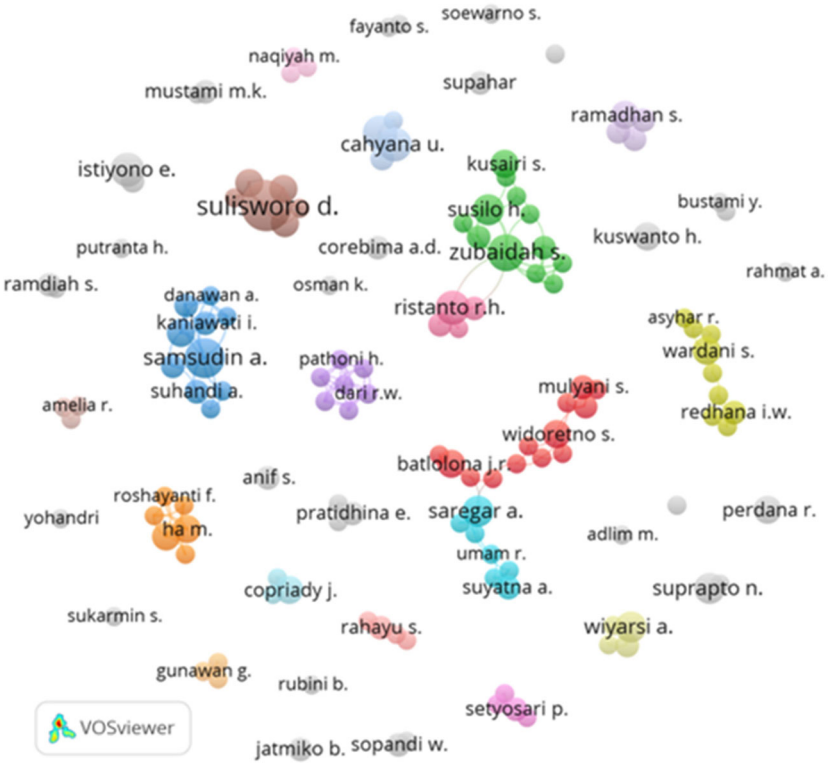

Figure 6. The collaborations among the leading authors.

cluster based on their close relationship in terms of papers written together (van Eck & Waltman, 2010). This analysis allows us to determine authors with the most publications and citations, as well as their collaborations. Co-authorship analysis reveals that a total of 287 sample papers in this study were authored by 689 science educators.

Table 2 shows that Sulisworo, Samsuddin, and Zubaidah were among the most productive authors as they produced the most publications. On the other hand, Saregar, Sulisworo, and Batlolona were among the influential authors as they gained the most citations. A check of the Scopus website reveals that all these authors have an H-index greater than 5, implying that they have been actively working on research and publications with substantial impact in their respective disciplines. The H-index informs us about a scientist's or scholar's production as well as the influence of his or her published works.

Figure 6 visualizes the collaboration of the leading authors. The size of nodes in this figure corresponds to the number of an author's publications, while a group of nodes connected to each other represents their collaboration in co-authoring those publications. As seen in Figure 6, the majority of the leading authors collaborated with some authors who did not make significant contributions. Only four of the leading authors collaborated with each other, including Zubaidah and Ristanto as well as Saregar and

Table 3. The ranks of the leading institutions based on the number of publications and citations.

Institution	Publications	Citations
Univ Negeri Yogyakarta	49	475
Univ Negeri Malang	33	330
Univ Pendidikan Indonesia	21	131
Univ Negeri Jakarta	20	130
Univ Sebelas Maret	18	123
Univ Ahmad Dahlan	15	111
Univ Negeri Surabaya	14	116
Univ Negeri Semarang	12	105
Univ Lampung	11	168
Univ Jambi	11	94

Batlolona. A search on Google Scholar reveals that Zubaidah and Ristanto have the same research interest in biology education. Similarly, Saregar and Batlolona are also from the same subject, physics education.

The leading institutions and their collaborations

Table 3 shows that Universitas Negeri Yogyakarta, Universitas Negeri Malang, and Universitas Pendidikan Indonesia were among the most prolific institutions, with the largest number of papers published. The first two universities, together with Universitas Lampung, were among institutions with the most significant impact in the field of science education in Indonesia since they received the greatest number of citations.

The trend of leading institutions may be related to their historical background and status. Except for Universitas Jambi, all institutions indicated in Table 3 were initially normal universities before eventually becoming regular universities. A normal university is an institution that formerly concentrated on offering teaching education programs to educate pre-service teachers with the standards of pedagogy and curriculum. Universitas Negeri Yogyakarta, Universitas Negeri Malang, and Universitas Pendidikan Indonesia were identified as among the first normal universities that were established during the early time of the independence of Indonesia (Martin & Faisal, 2019). These three universities are still regarded as the leading institutions in terms of providing teacher education programs (Suratno, 2012). It is also worth mentioning that, except for Universitas Ahmad Dahlan, all these universities are public institutions, which often have better-organized research groups and are awarded more national research funding.

Similar to the case of the leading authors, the size of nodes in Figure 7 corresponds to the number of publications affiliated with an institution, while the line connecting nodes represents the collaboration among institutions and the length of the distance represents how close their relationship was. As shown in Figure 7(a), numerous universities, especially those that were not regarded as the leading institutions, did not make research collaborations with each other. Likewise, some of the leading institutions did not collaborate with one another, but instead collaborated on research with universities that were not among the leading institutions, as seen in Figure 7(b).

The most intriguing characteristic reflected in Figure 7(b) is that several other leading institutions were identified to collaborate with each other despite being located in different regions, but not with other leading institutions located in the same region. Universitas Negeri Yogyakarta, for example, had no collaborations with Universitas Negeri Semarang nor Universitas Sebelas Maret even though these three leading institutions are located in Central Java. Instead, Universitas Negeri Yogyakarta collaborated with Universitas Negeri Surabaya, which is located in East Java. Similarly, although being in the same region of East Java, Universitas Negeri Malang did not work together on research with Universitas Negeri Surabaya. Rather, Universitas Negeri Malang worked with Universitas Negeri Jakarta, which is located in West Java. It is somewhat unexpected that, despite having several relationships with many non-leading universities, Universitas Sebelas Maret was identified as the only leading institution that had no collaborations with any other leading institutions.

In Indonesia, institutional collaborations predominantly involve researchers who were previously mentored by faculty members from other institutions. When a faculty member from one institution pursues an advanced degree program under the guidance of a faculty member from another university, they often engage in future collaborative research projects and jointly publish the results. National or institutional research grant is typically awarded to individual universities without a requirement for an outside partner from another institution. As a result, cooperation between universities was very rare.

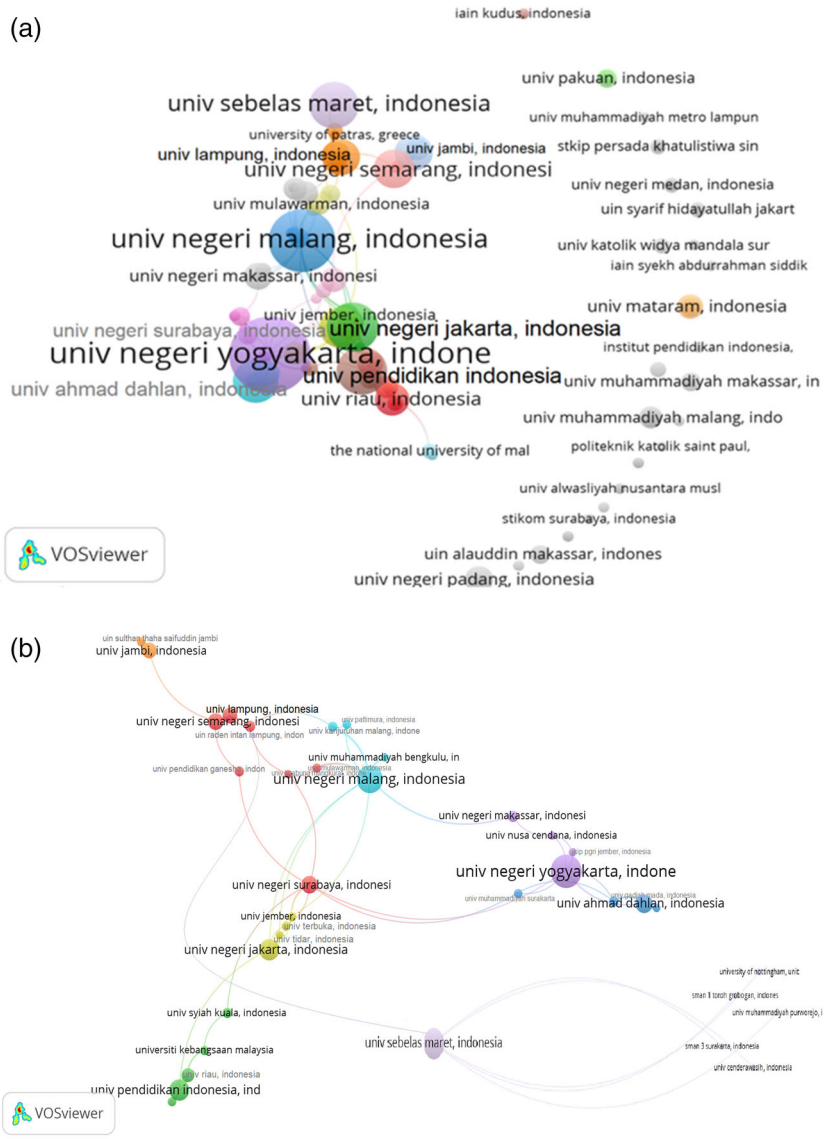

Figure 7. (a) The overall collaborations among institutions. (b) The collaborations among the leading institutions.

International collaborations

Figure 8 represents international research collaborations between Indonesian and international science educators. The thickness of the lines connecting the nodes corresponds to the frequency of the research collaborations that have been established. As evident from Figure 8, Malaysian and Japanese researchers collaborated with Indonesian science educators the most frequently, followed by those from South Korea, Turkey, and Taiwan. Despite the fact that Indonesian science educators have research collaborations with researchers from English-speaking countries such as the United Kingdom, Australia, and Canada, it is surprising that they have never collaborated with those from the United States, which is regarded as a global leader in science education.

Similar to the case of the leading institutions, collaborations between Indonesian researchers and academics from foreign nations are often carried out through educational channels. Indonesian scholars who study abroad usually collaborate on research with their supervisors from their host institutions in overseas countries. To increase the number of international networks, the Indonesian government has currently encouraged universities to conduct research projects that incorporate international collaborations. They even make international collaborations a prerequisite for research proposal applications in order to be eligible for research funding (The Ministry of Higher Education of Indonesia, 2017).

Figure 8. International collaborations.

Table 4. The major research topics of the reviewed papers according to the NARST strands.

Research Topics	Number of papers
Learning classroom contexts and learner characteristics	134
Educational technology	50
Learning students' conceptions and conceptual change	37
Cultural, social and gender issues	25
Teacher education	15
Teaching	13
Goals and policy, curriculum, evaluation, and assessment	12
Informal learning	1
History, philosophy, epistemology, and nature of science	0

Various research topics

Various research topics according to the NARST strands

Table 4 highlights the overall trend in research topics among the reviewed papers according to the NARST strands. As seen in this table, Indonesian science educators among different science education subjects have the greatest interest in investigating the topic of learning classroom contexts and learner characteristics. Studies on this topic include those by Sulisworo et al. (2016), which looked at how well Moodle performed as a learning management system to enhance the quality of cooperative-blended learning, and by Zubaidah et al. (2018), which looked at how well a learning strategy known as reading-concept mapping-reciprocal teaching performed in terms of enhancing students' critical thinking skills. Educational technology is the second major topic that has appealed Indonesian researchers. Two examples of studies on this topic are one by Wardani et al. (2017) that examined the integration of android-based chemistry board game into inquiry-based instruction to improve students' critical thinking skills, and another by Cahyana et al. (2017) that examined the use of mobile game-based learning to improve students' understanding toward chemistry concepts.

The topic of learning students' concepts and conceptual change has been also a popular one among Indonesian scholars. A study on remedying students' conceptual understanding of Newton's second law through the express-refute-investigate conceptual change learning strategy by Fratiwi et al. (2020) and a systematic review of students' mental model regarding chemistry concepts by Wardah and Wiyarsi (2020) are two examples of this topic. Cultural, social, and gender issues are the last common key topic that has been drawing Indonesian science educators. Examples of research on these issues include a study by Rahmawati and Ridwan (2017), that investigated the role of ethno-chemistry in culturally responsive teaching to empower students' performance in learning chemistry and a study by Rachmatullah et al. (2017) that investigated the influence of curriculum together with gender and students' favourite of subject on their achievement of science learning.

Figure 9 highlights the modest variances in the major research topics that Indonesian science educators have commonly found compelling in each discipline of science education during the past six years, when the number of publications began to agglomerate. On the one hand, the trend of major research topics is consistent with the findings of the CC Tsai group, which found that learning classroom

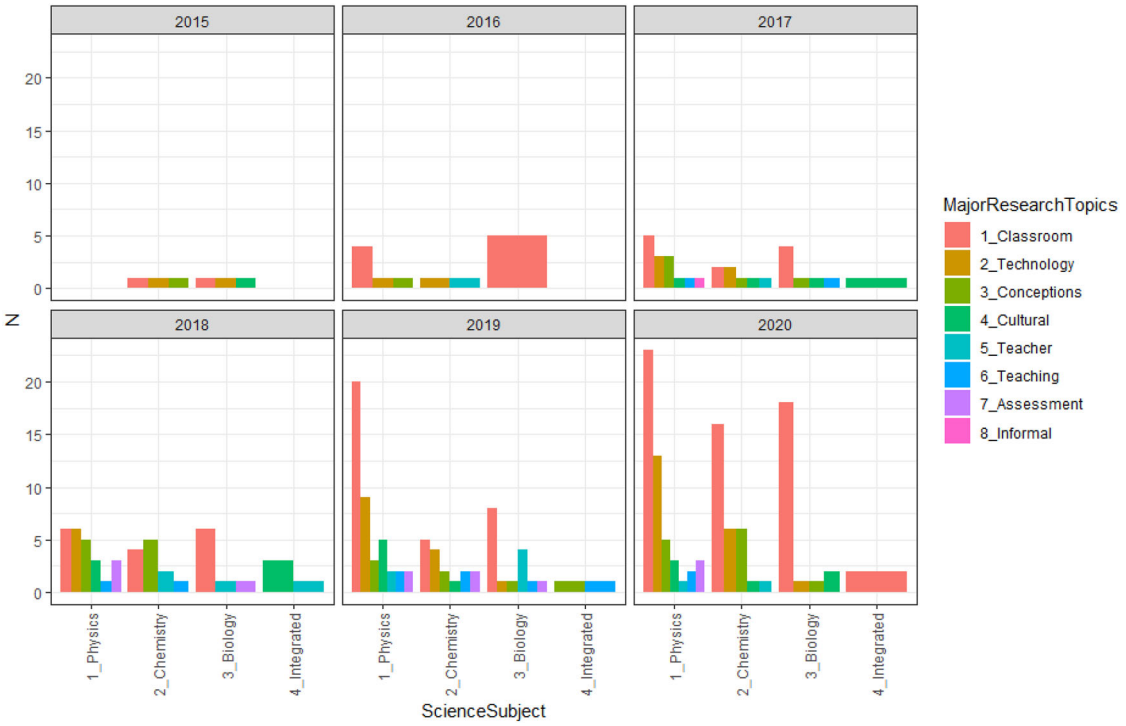

Figure 9. The modest variances in the major research topics in every science education subject during the past six years.

environments and learner characteristics, as well as learning students' concepts and conceptual change, received the most attention from worldwide science educators (Lin et al., 2019). On the other hand, the trend of the current study differs from the international context in that educational technology was one of the least explored topics reported in the CC Tsai group studies.

The trend of various research topics in the current study appears to make sense, as all the sample papers focused on science education in secondary schools. Such studies are typically concerned with how to create an effective and meaningful learning environment through integrating technology into instructional classroom practices in order to improve students' achievement while also helping them address misconceptions that prevent them from acquiring expected conceptual understanding. Such goals have piqued the interest of scientific educators, who are expected to overcome the challenges of preparing pupils for future success while studying science at the university level through effective secondary education. However, this trend in research topics reveals that Indonesian science educators placed too much emphasis on students' aspects while overlooking the critical role of teachers, their education and professional development, as well as the important function of policy and curriculum in achieving the desired learning outcomes. They also made little effort into investigating the value of learning in environments outside the classroom setting, which may have a significant impact on how well children study science and acquire knowledge and skills necessary to succeed in this subject.

It is surprising that none of the studies conducted by Indonesian science educators have addressed the topics of history, philosophy, and the nature of science (NOS). This finding appear to be consistent with research by Olson (2018) which investigated whether the NOS component was included in documents describing international science education standards that were retrieved from nine different countries, including Indonesia. It was found that the document from Indonesia was the only science education standard that did not contain the NOS component at all. In fact, most research on the NOS places a strong emphasis on how students perceive science, which is likely to have an influence on how well they understand various science disciplines (Abd-El-Khalick & Lederman, 2000).

According to a Google Scholar search, Indonesian researchers have authored a few articles on NOS. For instance, Prima et al. (2018) designed a teaching material that contain an experiment to promote students' appreciation of the NOS, while T. B. Wardani and Winarno (2017) investigated the effect of inquiry-based laboratories in enhancing students' comprehension of the NOS. The first paper, however,

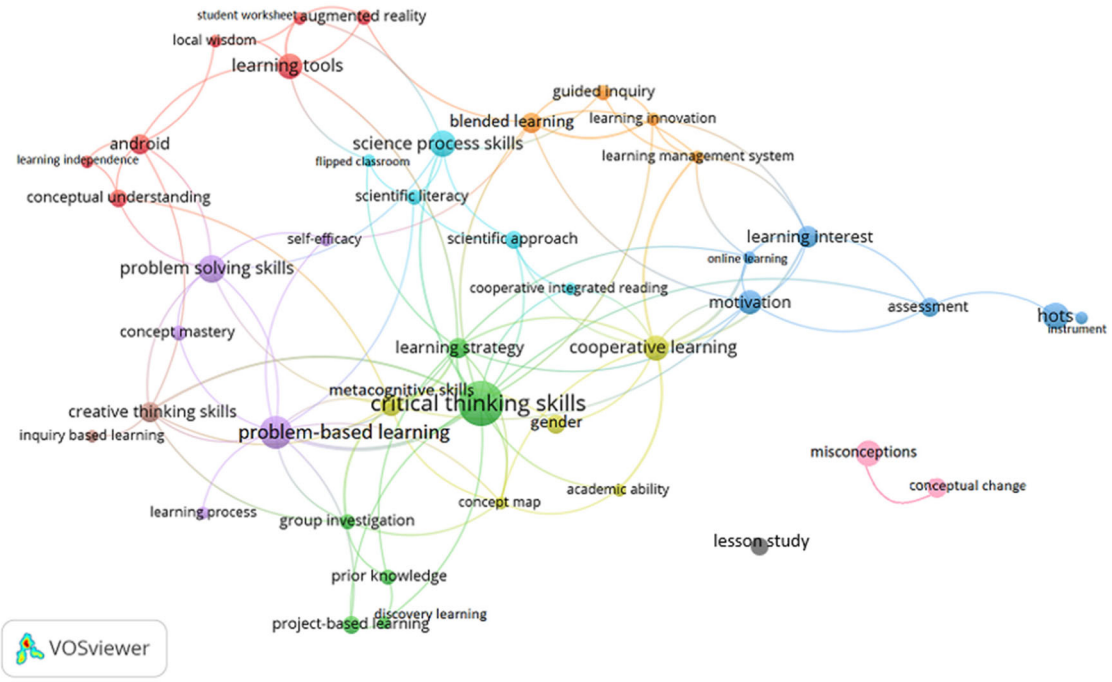

Figure 10. The major research topics according to the most used keyword.

Table 5. The clusters of major research topics in the reviewed papers.

Main topics	Related topics
Critical thinking skills	Science process skills, Scientific approach, Scientific literacy, CIRC (Cooperative integrated reading and composition), Flipped classroom
Problem-based learning	Problem solving skills, Concept mastery, Learning process, Self-efficacy
Cooperative learning	Learning strategy, Metacognitive skills, Gender, Academic ability, Concept map
Higher order thinking skills (HOTS)	Motivation, Learning interest, Assessment, Instrument, Online learning
Learning tools	Android, Conceptual understanding, augmented reality, Learning independence, Local wisdom, Student worksheet
Blended learning	Guided inquiry, Learning innovation, Learning management system
Creative thinking skills	Inquiry-based learning
Project-based learning	Group investigation, Prior knowledge, Discovery learning
Misconceptions	Conceptual change
Lesson study	–

was excluded from the samples because it lacked a part on expert judgment with reference to the developed teaching material. The second work was not included in the samples because it was published in a journal that was not indexed by Scopus or Web of Science.

Various research topics according to the most used keywords

Co-occurrence analysis counts the number of times each keyword appears in the reviewed papers and assigns a group of keywords to a certain cluster based on their repeated appearances in several papers at the same time (van Eck & Waltman, 2010). As portrayed in Figure 10, this analysis makes it possible to identify major topics as well as their linkages to many other prominent topics highlighted in the reviewed papers. The size of the nodes in this figure correlates to the frequency with which the highlighted keywords appear, demonstrating the significance of the corresponding topics in the reviewed papers. A group of nodes connected to one another and coloured the same symbolizes research topics that are closely related as they were commonly identified together in the same paper. As indicated in Table 5, there were 10 clusters of major research topics, with the most prominent among each becoming critical thinking skills, problem-based learning, cooperative learning, HOTS, learning tools, blended learning, creative thinking skills, and project-based learning, misconceptions, and lesson study.

The group of keywords in cluster one implies that Indonesian science educators have been interested in examining critical thinking as an essential skill that students need to acquire and its relationship to science process skills and scientific literacy, as well as how these skills may be promoted through learning strategies that

adopt scientific approaches, cooperative models, and flipped classroom practices. In cluster two, Indonesian scholars appear to pay attention to how problem-based learning and its associated learning processes may be an effective instructional strategy to develop and enhance students' problem-solving skills, concept mastery, and self-efficacy. Cluster three suggests that Indonesian researchers have been attracted to investigate cooperative learning along with the role of concept map strategy as a teaching approach to promote students' metacognitive skills as it may have an impact on increasing academic ability, as well as how the variables may or may not be varied among students of different genders. As reflected in cluster four, Indonesian science educators seem to be concerned with examining how students' motivation or interests may influence their higher order thinking skills, as well as how to select or develop valid instruments to measure these skills and how online learning may be an effective learning strategy to teach students regarding these skills.

The integration of digital technology in classrooms teaching and learning appears to have also appealed the interest of Indonesian science educators as implied in cluster five, where they have studied how android-based learning tools such as augmented reality may be combined with students' worksheets to facilitate their need toward learning independence while also improving their conceptual understanding, as well as how these digital applications may be also used as means to incorporate local wisdom value in classroom. In line with the previous cluster, keywords in cluster six indicate that Indonesian scholars have been also interested in studying the role of learning management systems in managing blended learning as one of the distance learning modes, as well as the possibility of integrating such a technology into guided inquiry-based instruction as the way of introducing innovation in learning science. More than that, Indonesian researchers seem to be intrigued by investigating how inquiry-based learning may effectively help students increase their creative thinking skills as demonstrated by keywords in cluster seven.

The group of keywords in cluster eight appears to indicate that some Indonesian science educators have been focusing on studies related to the role of prior knowledge in the context of project-based learning, which is one form of discovery learning, with the goal of improving the quality of students' group investigation. Cluster nine implies that Indonesian scholars have also worked hard to understand students' misconceptions and develop instructional methods that may be beneficial in helping students experience conceptual change in order to address their alternative conceptions. Even though the last cluster has no correlation with any other topics, it confirms that science educators in Indonesia have devoted special attention to researching classroom teaching methods carried out in lesson study settings. This finding appears to be the impact of a long-term partnership between the Japan International Cooperation Agency (JICA) and three of Indonesian leading institutions for teacher education, namely Universitas Negeri Malang, Universitas Negeri Yogyakarta, and Universitas Pendidikan Indonesia, to introduce and disseminate lesson study as the excellent community for fostering the teaching and learning of science subjects throughout secondary schools in Indonesia (Suratno, 2012).

Ultimately, we may also draw links between primary keywords in order to interpret the findings regarding the major research topics. For example, the emergence of prominent keywords such as critical thinking skills, HOTS, creative thinking skills, and problem-solving skills reveals that Indonesian researchers have been essentially engaged in researching subjects of studies pertaining to 21st century skills. It is also worth mentioning that the absence of topics about the nature of science in these clusters reaffirms the trend of the major research topic discussed in the preceding section, in which Indonesian scholars have yet to devote much attention to examining such a key topic of science education research.

The highly influential literature

Co-citation analysis with the unit of references identifies all sources that were cited collectively by two or more of the reviewed papers and determines the frequency of this citation (van Eck & Waltman, 2010). This analysis helps us recognize the most highly cited literature among the reviewed papers, revealing the significant influence of that literature. Appendix B displays all literature authored by either foreign or Indonesian scholars that received the most citations from the reviewed papers. Most of these references appear to be consistent with the findings regarding the major research topics reported in the previous section. For example, The article by Aizikovitsh-Udi and Amit (2011) indicates that Indonesian researchers have been engaged in a variety of research topics, including critical and creative thinking skills as the two of the components of 21st century skills, their relationship to science process skills and

scientific literacy, as well as how problem-based learning may be effective instructional modes to promote these skills. Similarly, the article by Baran and Maskan (2010) demonstrates a strong interest among Indonesian researchers in investigating the potential of laboratory and project-based learning as instructional approaches to enhance students' learning achievement. Furthermore, the article by Ichsan et al. (2019) implies that HOTS, as one of essential learning outcomes, is among the primary research subjects that have piqued the interest of Indonesian researchers.

The article by Çepni et al. (2017) supports the notion that Indonesian science educators have been concerned with doing research on students' misconceptions as well as developing alternative teaching strategies to deal with such a problem. On the other hand, the article by Arista and Kuswanto (2018) suggests Indonesian science educators' interest in conducting studies that focus on the role of technology in creating more meaningful and interactive learning models to facilitate students' acquisition of conceptual understanding. Eventually, the presence of the article by Baloche and Brody (2017) as one of the influential literature reveals that Indonesian science educators have been actively working on examining role of cooperative learning as innovative instructional strategy to promotes students' social learning.

Various research methods

Figure 11 reveals that Indonesian science educators have consistently favoured quantitative over qualitative and mixed methods over time. Figure 12 details the trend of specific sub research methods applied across different science education subjects during the past six years, when the number of papers started to accumulate. As apparent from Figure 12, pre- and quasi-experiment have become the most prevalent quantitative methods among Indonesian researchers, followed by descriptive and survey. Those that employed qualitative methods, on the other hand, did not appear to take a variety of approaches, with nearly all of them being basic qualitative.

The trend of both main and sub research methods described in the current study is quite comparable to the study of Sozbilir et al. (2012), which found that the majority of Turkey's science educators preferred employing quantitative over qualitative and mixed methods, with the dominant of quantitative approach being quasi experimental, followed by survey and descriptive. Regarding the fact that Turkish researchers favoured quasi experiment among other quantitative approaches, Sozbilir et al. (2012) explained that this finding is reasonable given that most of the studies were conducted in the environment of schools with pre-determined groups of pupils and teachers. In response to the low number of qualitative approaches, Sozbilir et al. (2012) stated that this tendency reflects a lack of expertise and experience with such research methods among Turkey's science educators. The same argument seems to be true in explaining the results of the current study.

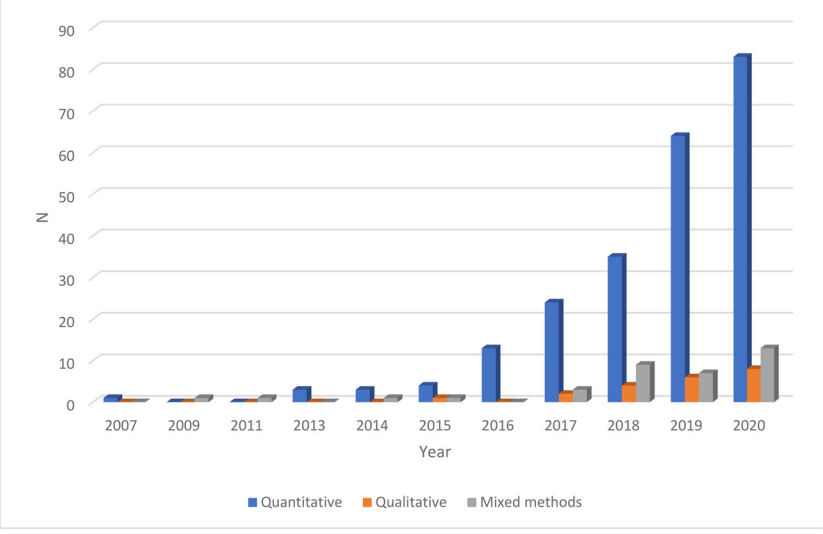

Figure 11. The various of main research methods employed in the reviewed papers over years.

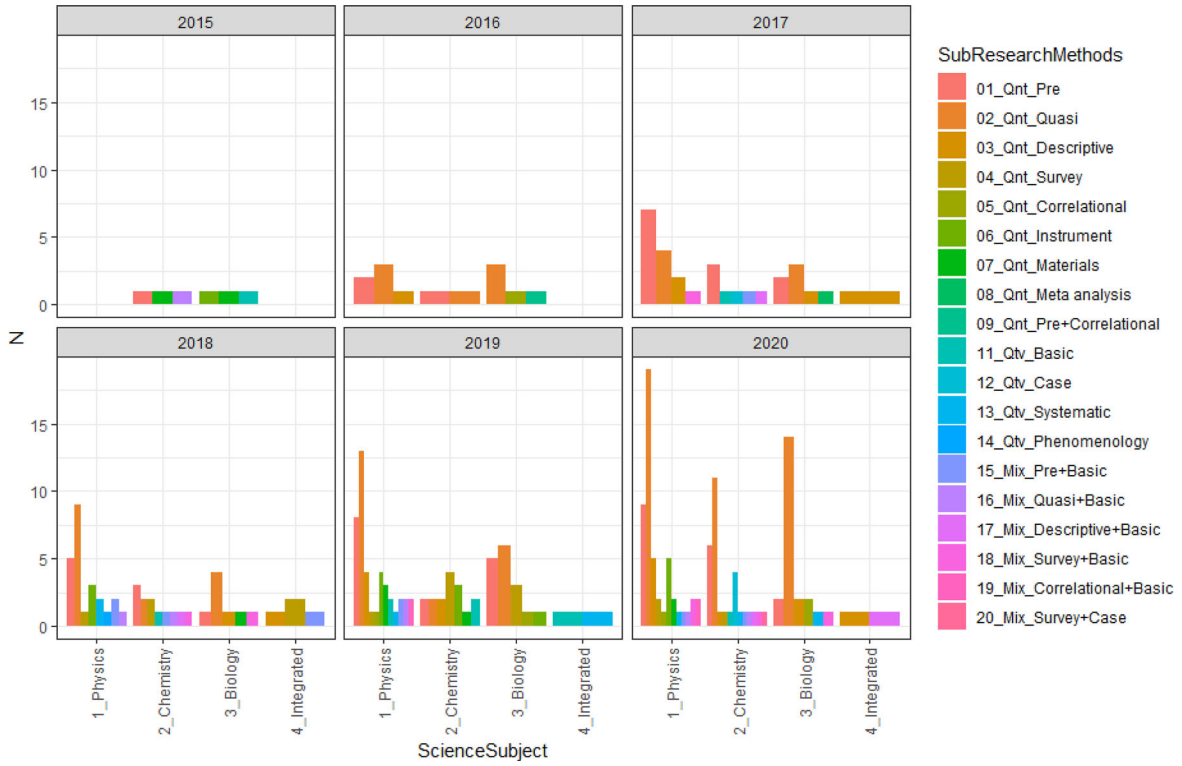

Figure 12. The trend of sub research methods applied across different science education subjects during the past six years.

Because the systematic review assigned each article to one specific category of research topics and methods, this technique made it possible to do crosslink analysis between these two variables, describing how Indonesian science educators have approached their research, as indicated in Figure 13. The most striking feature of this figure is how, throughout the time, Indonesian science educators who were interested in conducting research on learning classroom contexts and learner characteristics favoured quasi-experiments at most, regardless of the wide range of methods they have employed. This tendency appears to make sense given that classroom studies frequently utilize control and experimental groups to generate more reliable data when examining whether a method of instruction improves students' academic performance. Similar pattern was observed among Indonesian researchers who were interested in the topic of educational technology, except that they preferred pre-experimental over quasi-experimental methods. This pattern may be explained by the fact that it often takes multiple pilot projects with more basic experimental designs to successfully integrate technology into classroom teaching practices.

Another interesting finding captured from Figure 13 is that Indonesian scholars who have studied the topics of learning students' conceptions and conceptual changes seem to be more open to a variety of quantitative and qualitative methods, as well as a combination of both, than those who have studied other topics. This finding seems reasonable given that researchers in this area typically conduct a variety of investigations, including identifying students' understanding of scientific concepts, misconceptions they encounter, and alternative teaching methods to remedy these misconceptions. All these inquiries must undoubtedly be conducted in a variety of methods. As for Indonesian scholars who have specialized in the study of teacher education and teaching, they were identified to be among those who employed surveys more frequently than other research methods. This tendency also looks to be sensible, as studies involving teachers and their teaching practices typically aim to understand teachers' opinions or attitudes about the adoption or implementation of a certain policy or new instructional strategy.

The last important tendency revealed by Figure 13 is that research on the topic of goals and policy, curriculum, evaluation, and assessment was typically conducted using the method of descriptive developing instrument. Even though it makes sense that assessment is directly tied to creating and implementing instruments, studies of this topic should take into account a variety of different approaches, since assessment has lately embraced a variety of alternative forms other than testing.

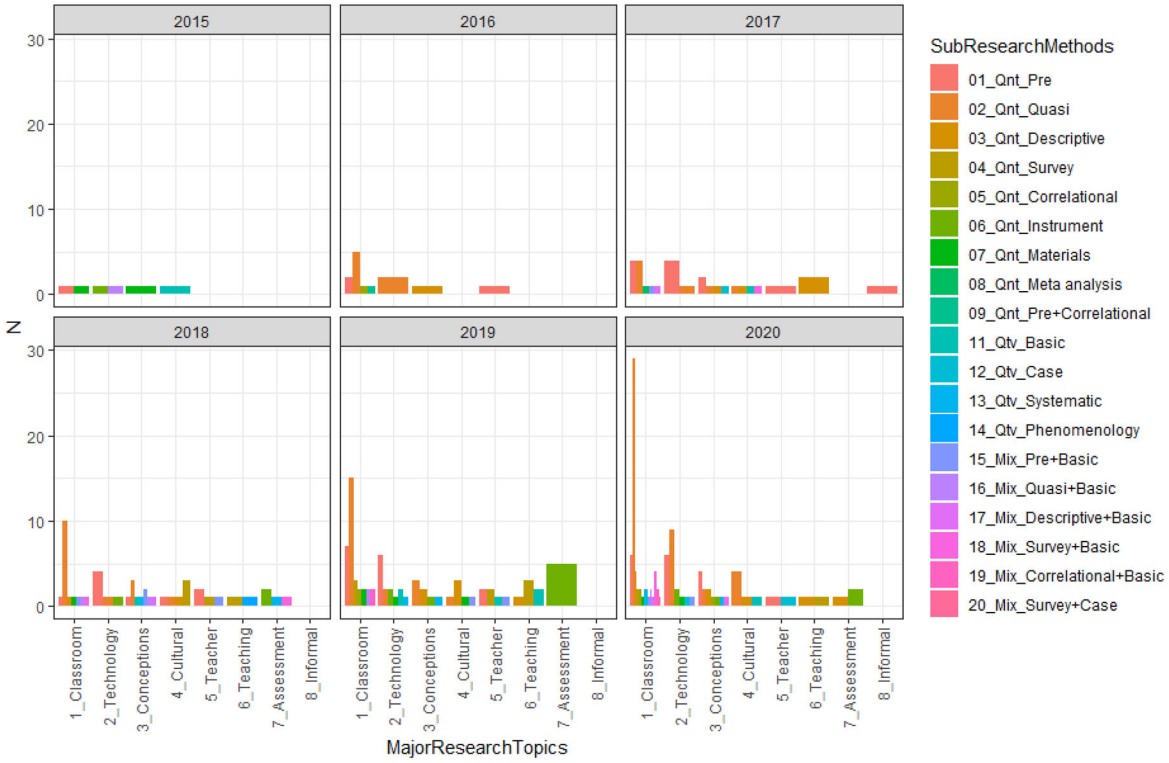

Figure 13. The details of sub research methods used by authors among the major research topic during the past six years.

Concluding remarks

The aim of the current study was to portray the landscape of science education research in the context of Indonesian secondary schools over the past two decades, and there are significant findings. First, our data demonstrate that publications regarding Indonesian science education have grown dramatically only since 2017. This evidence appears to explain the impact of the government policy that requires international publication as one of the criteria for tenure promotion among institutional professors. Second, the very low numbers of Indonesian publications in prestigious international journals of science education suggests that there is still a demand for professional development geared toward faculty members, science teachers, and graduate students with the goal of improving their ability to write manuscripts in adequate English while adopting appropriate rhetorical styles. Third, collaboration among the leading authors is generally confined to individuals associated with large institutions that have historically offered teacher education programs since their inception. In terms of international collaboration, while Indonesian science educators have collaborated with researchers from several English-speaking nations, they have not collaborated with those from the United States, which is the global leader in science education. Fourth, according to the NARST strands, the research topics that have piqued the interest of Indonesian science educators were primarily related to learning classroom contexts and learner characteristics, educational technology, as well as learning students' conceptions and conceptual change. This finding suggests that research topics in Indonesian secondary schools have mostly focused on the objective of examining the efficacy of teaching strategies along with the integration of technology into classroom teaching practices in order to improve students' achievement. However, the most prevalent co-occurrence keywords, as well as the highly influential literature, reveal that Indonesian researchers have been engaged in investigating issues pertaining to the 21st century skills, such as critical thinking skills, HOTS, creative thinking skills, and problem-solving skills. Eventually, when it comes to research methods, Indonesian scholars generally favour quantitative over qualitative approaches, with pre- and quasi-experiment being the most widespread, particularly when conducting research regarding learning classroom contexts and learner characteristics. Those who employed qualitative methods did not appear to take a wide range of approaches, with nearly all of them being basic qualitative, indicating a lack of expertise and experience with such research methods among Indonesian science educators. This problem highlights the necessity for a professional development

program for university professors, science instructors, and graduate students aimed at enhancing their knowledge and abilities in qualitative research approaches.

The current study is a subset of a larger study that aims to map the trends of science education research in the context of Indonesia at all educational levels, using sample papers retrieved from both the Scopus and Web of Science (WOS) databases. The next study will investigate several aspects not covered yet in the current study, such as replicating the design employed in the current study while using sample papers retrieved from the WOS with different levels of education, as well as whether or not the results will be comparable. Given that the current study identified 10 clusters of topics that represent the key research interests of Indonesian scholars, the next study will focus on conducting systematic reviews and bibliometrics for each of these narrower topics. Furthermore, the fact that the majority of the reviewed papers were studied through quantitative methods with pre- and quasi-experimental designs have contributed to our decision to conduct meta-analysis research on some relevant topics such as problem-based learning, project-based learning, inquiry-based learning, and cooperative learning. On the other hand, the small number of qualitative publications in the current study prompted us to analyse their quality using a meta-synthesis approach, which is a research synthesis technique specifically designed to examine qualitative research. Because the current study did not look further into whether the leading authors focused on a more concentrated or random topic over time, the next study will also aim to examine the expertise area of Indonesian science educators as judged by the focus of their publications.

Finally, it is important to point out that there is still need for future research to enrich the results of the current study. First, because the current study relied on journals as the source of sample papers, further examination may be conducted using graduate theses and dissertations, as these types of literature are also a formal platform to present scientific research and a significant source for drawing a map of science education progress, as what Calik et al. (2008) did in the context of Turkey. However, considering that none of Indonesian institutions has a corporation with the ProQuest as the primary database for theses and dissertations, future work may require an extra effort to collect these documents from the targeted institutions. Second, given that the current study only focused on the context of Indonesia, further research may expand the scope to include all Southeast Asian countries as they share numerous commonalities such as social culture, language, and ethnicity, as what Medina-Jerez (2016) did in the context of Latin American countries. Third, considering that Indonesian science educators have generally contributed more to international conference proceedings than to international journals, it may be appealing to replicate the design of the current study using papers authored by Indonesian science educators and published in IOP and AIP Publishing, as what Santos et al. (2023) did in the context of Australia, Canada, and China. Lastly, while it is stated in the method section that the inclusion of only papers with English-written manuscripts is primarily for reasons of accessibility among scholars from various countries, a future study using sample papers written in Indonesia is also necessary to present a more comprehensive picture of science education research in Indonesia. However, as none of the bibliometrics tools supports analytical procedures in languages other than English, such a study can only be carried out via systematic review method.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendices

Appendix A. The list of journals, their quartiles according to SJR, affiliating countries, and the number of corresponding samples

Journal	Quartile	Country	Number of articles	Journal	Quartile	Country	Number of articles
INT J SCI EDU	Q1	United Kingdom	2	REV MEX FIS E	Q3	Mexico	1
INT J EMERG TECHNOL LEARN	Q1	Austria	5	TEM J	Q3	Serbia	2
INT J SCI MATH EDUC	Q1	Netherlands	2	ASIA-PAC FORUM SCI LEARN TEACH	Q4	Hongkong	9
INT J MOBILE LEARN ORGAN	Q1	Switzerland	1	INT J ASSESS EVAL	Q4	United States	1
INT RES GEOGR ENVIRON EDUC	Q1	United Kingdom	1	INT J LEARN CHANG	Q4	Switzerland	1
J PENDIDIKAN IPA INDONES	Q2	Indonesia	59	J EDU SOC RES	Q4	Poland	1
INT J INSTR	Q2	Turkey	38	PEDAGOGIKA	Q4	Lithuania	1
J TURK SCI EDUC	Q2	Turkey	15	UNIVERS J EDU RES	Not assigned	United States	36
J BALTIC SCI EDU	Q2	Lithuania	10	J EDUC GIFTED YOUNG SCI	Not assigned	Turkey	15
EURASIA J MATH SCI TECHNOL EDUC	Q2	Turkey	5	INT J SCI TECHNOL RES	Not assigned	India	12
J TECHNOL SCI EDUC	Q2	Spain	3	PER TCHE QUIM	Not assigned	Brazil	6
INT J TECHNOL ENHANCED LEARN	Q2	Switzerland	2	INT J INNOV CREAT CHANGE	Not assigned	United Kingdom	4
INT EDUC VOCAT GUIDANCE	Q2	Netherlands	1	J SCI EDUC	Not assigned	China	4
INT J ENGI PEDAGOGY	Q2	Austria	1	HUMANIT SOC SCI REV	Not assigned	India	3
PHYS EDUC	Q2	United Kingdom	1	ASIAN SOC SCI	Not assigned	Canada	2
TURK ONLINE J DISTANCE EDUC	Q2	Turkey	1	INTERN EDUC STUD	Not assigned	Canada	2
WORLD TRANS ENG TECHNOL EDU	Q2	Australia	1	MAN INDIA	Not assigned	India	2
CAKRAWALA PENDIDIK	Q3	Indonesia	7	OPCION	Not assigned	Venezuela	2
EUROPEAN J EDUC RES	Q3	Netherlands	5	TURK ONL J EDU TECH	Not assigned	Turkey	2
INTL J LEARN TEACH EDU RES	Q3	Mauritius	4	ADV SCI LETT	Not assigned	United States	1
PERTANIKA J SOC SCI HUMANIT	Q3	Malaysia	3	INT J ENVIRON SCI EDUC	Not assigned	Turkey	1
EURASIAN J EDUC RES	Q3	Turkey	2	MEDITERRANEAN J SOC SCI	Not assigned	Italy	1
INT J EVAL RES EDUC	Q3	Indonesia	2	PROBL EDUC 21ST CENTURY	Not assigned	Lithuania	1
CENT EDUC POLICY STUD J	Q3	Slovenia	1	TESOL INT J	Not assigned	Philippines	1
INT J INF COMMUN TECHNOL EDUC	Q3	United States	1	CHEMISTRY	Not assigned	Bulgaria	1
NEW EDUC REV	Q3	Poland	1	INT J LEARN TEACH	Not assigned	Unknown	1

Appendix B. The most highly cited literature in the reviewed papers

Authors	Year	Title	Source
Baran, M., Maskan, A.	2010	The effect of project-based learning on preservice physics teachers' electrostatic achievements	Cypriot Journal of Educational Sciences, http://archives.un-pub.eu/index.php/cjes/article/view/117/pdf_24
Arista, F. S., Kuswanto, H.	2018	Virtual physics laboratory application based on the android smartphone to improve learning independence and conceptual understanding	International Journal of Instruction, https://doi.org/10.12973/iji.2018.1112a
Hake, R. R.,		Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses	American Journal of Physics, https://doi.org/10.1119/1.18809
Lestari, P., Ristanto, R., Miarsyah, M.		Analysis of conceptual understanding of botany and metacognitive skill in pre-service biology teacher in Jakarta	Journal for the Education of Gifted Young, https://doi.org/10.17478/jegys.515978
Aizikovitsh-Udi, E., Amit, M.	2011	Developing the skills of critical and creative thinking by probability teaching	Procedia – Social and Behavioral Sciences, https://doi.org/10.1016/j.sbspro.2011.03.243
Baloche, L., Brody, C. M.	2017	Cooperative learning: exploring challenges, crafting innovations	Journal of Education for Teaching
Birgili, B.		Creative and critical thinking skills in problem-based learning environments	Journal of Gifted Education and Creativity, https://doi.org/10.18200/jgedc.2015214253
Çepni, S., Ulger, B. B., Ormanci, U.	2017	Pre-service science teachers' views towards the process of associating science concepts with everyday life	Journal of Turkish Science Education, https://doi.org/10.12973/tused.10208a
Deboer, G.E.		Scientific literacy: another look at its historical and contemporary meanings and its relationship to science education reform	Journal of Research in Science, https://doi-org. /10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L
Fuad, N. M., Zubaidah, S., Mahanal, S., Suarsini, E.	2017	Improving junior high schools' critical thinking skills based on test three different models of learning	International Journal of Instruction, https://doi.org/10.12973/iji.2017.1017a
Hilton, A., Nichols, K.		Representational classroom practices that contribute to students' conceptual and representational understanding of chemical bonding	International Journal of Science Education, https://doi.org/10.1080/09500693.2010.543438
Hofstein, A., Lunetta, V. N.		The laboratory in science education: foundations for the twenty-first century	Science Education, https://doi.org/10.1002/sce.10106
Ichsan, I. Z., Sigit, D. V., Miarsyah, M., Ali, A., Arif, W. P., Prayitno, T. A.	2019	HOTS-AEP: higher order thinking skills from elementary to master students in environmental learning	European Journal of Educational Research, https://doi.org/10.12973/eu-jer.8.4.935
Jackson, J., Dukerich, I., Hestenes, D.		Modeling instruction: an effective model for science education	Science Educator, https://files.eric.ed.gov/fulltext/EJ851867.pdf
Liu, G., Fang, N.		Student misconceptions about force and acceleration in physics and engineering mechanics education	International Journal of Engineering Education, 32 (1), pp. 19–29