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Research Mapping of E-Assessment in Physics and Science Education: A Bibliometric Analysis

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ABSTRACT

Assessment is a fundamental component of physics and science education; however, the implementation of e-assessment faces unique challenges related to the complexity of abstract concepts and the limitations of comprehensively mapping research trends. This study aims to analyze publication trends, collaboration patterns, knowledge structures, and future development directions of e-assessment in physics and science education through a bibliometric approach. Data were collected from the Scopus database in March 2026 using keywords related to e-assessment and physics or science education, yielding 190 documents from 2016 to 2026. Analysis was conducted using VOSviewer for network mapping and visualization, and Microsoft Excel for preliminary analysis. The results indicate that the number of publications increased significantly following the COVID-19 pandemic, with the United States as the primary contributor and Indonesia ranking fourth. The mapping reveals that research focus has shifted from merely applying digital technology toward integrating artificial intelligence and large language models into adaptive and personalized assessment. New findings also indicate the emergence of atomized problem-solving approaches and the use of translanguaging as an inclusive and equitable assessment practice. In conclusion, e-assessment in physics and science education is evolving toward a convergence of technological innovation and robust pedagogy, with the primary benefit of providing a roadmap for researchers, educators, and policymakers in developing assessments that are adaptive, personalized, and responsive to the cognitive, linguistic, and cultural diversity of students in the digital age.

INTRODUCTION

Assessment is a fundamental component of education that serves to diagnose and evaluate students' learning achievements, including their cognitive, affective, and psychomotor skills (Limbu, 2024). In the context of physics and science education, assessment plays a highly strategic role given the abstract and complex nature of physics, which requires a deep conceptual understanding. Assessment in physics and mathematics not only serves to measure conceptual understanding but also students' ability to analyze and synthesize scientific phenomena (Braun, 2024; Kuo, 2022). The use of formative assessment has been shown to be effective in improving students' conceptual understanding without compromising their quantitative problem-solving skills (Lichtenberger et al., 2024). Furthermore, the main challenges in physics assessment include identifying students' misconceptions, low science literacy, and a tendency toward inauthentic assessment due to an overemphasis on cognitive aspects (Sinaga, 2025). Therefore, a comprehensive and continuous assessment approach is essential for designing targeted learning interventions to holistically improve the quality of learning outcomes.

Advances in digital technology have brought about significant transformations in educational assessment practices. E-assessment, or electronic assessment, has emerged as a new paradigm that utilizes information technology to design, implement, and evaluate the learning assessment process. E-assessment is defined as a systematic method for collecting information about learners and the learning process by utilizing electronic technology, with the aim of determining learners' dispositions toward the use of such technology (Blegur et al., 2024). This definition emphasizes that e-assessment is not merely a transformation from a paper-based format to a digital one, but rather a planned and intelligent approach to ensuring authentic value in its design and implementation.

The COVID-19 pandemic has been a major catalyst for accelerating the adoption of e-assessment worldwide, particularly as educational institutions were forced to shift all learning and assessment processes to an online format (Bozkurt, 2023). In this emergency situation, there has been a growing realization that e-assessment holds great potential to improve the quality of learning processes and outcomes, including providing personalized feedback and fostering student autonomy (Pusa & Dinçer, 2025; Pillay, 2024). However, the implementation of e-assessment also faces significant challenges, such as the digital divide, low digital literacy, and issues related to academic integrity and cheating (Pillay, 2024). Research indicates that the success of e-assessment heavily depends on adapting assessment strategies, improving technological infrastructure, and developing assessment literacy among both educators and students (Zeng, 2024). Looking ahead, the pandemic experience has driven a paradigm shift in assessment from traditional approaches toward a more flexible, adaptive, and learner-centered digital assessment model (Adhikari et al., 2025).

Physics, as a field that relies heavily on mathematical reasoning, experimentation, and an understanding of abstract concepts, requires an assessment approach capable of accommodating this complexity. A systematic review of online exams in higher education in physics and mathematics found that invigilated closed-book exams (ICBE) tend to be more effective for measuring lower-order cognitive skills such as recall and comprehension, while higher-order cognitive skills such as analysis and synthesis are better assessed through open-book exams that provide access to various resources (Braun, 2024). These findings indicate that e-assessment in physics requires a specialized design that takes into account the hierarchy of cognitive skills. In addition, challenges in implementing e-assessment include teachers' difficulty in accurately assessing student performance, obstacles related to the use of technology, selecting the appropriate assessment methods, and the lack of systematic evaluation guidelines. These obstacles lead educators to miss in-person learning due to the loss of direct communicative interaction (Blegur et al., 2024).

Although research on e-assessment in physics and science education has grown rapidly, particularly in the post-pandemic era, there remains a significant gap in the form of a comprehensive mapping of trends, patterns, and directions for research development in this field. Although assessment plays a fundamental role in physics education with extensive research exploration, a comprehensive bibliometric analysis that synthesizes trends and identifies research gaps is still unavailable (Nurjanah et al., 2025). Bibliometric analysis offers a suitable methodology for understanding the structure of knowledge and the evolution of research within a field. Studies of publication trends using bibliometric methodologies enable researchers to identify emerging science and technology in a specific field, as well as make meaningful and prioritized decisions regarding future research (Blegur et al., 2024).

In the context of e-assessment in physics and science education, bibliometric analysis can answer crucial questions such as: (1) How have publication trends evolved over time? (2) What are the research topics of focus? (3) Who are the most productive authors, institutions, and countries? (4) What patterns of scientific collaboration have emerged? (5) What research gaps still need to be addressed? (6) In which direction will this research develop in the future? The bibliometric approach also enables the identification of research clusters through keyword co-occurrence analysis, co-authorship analysis, and citation analysis. In the analysis of science literacy, this approach yields three co-occurrence clusters encompassing educational literacy, scientific literacy, and humanities, providing a visual representation of the scope of the research (Ilma & Kuswanto, 2025).

The study titled "E-Assessment in Physics and Science Education: A Bibliometric Analysis" derives its originality from its specific focus, which combines two key dimensions: e-assessment as a modern assessment approach, and the specific domain of physics and science education. Unlike the study by Nurjanah et al. (2025), which generally discusses assessment in physics education, this study specifically focuses on e-assessment, a subset with its own distinct characteristics and challenges (Nurjanah et al., 2025). Furthermore, this study also differs from the study by Blegur et al. (2024), which examines online assessment in physical education; although it shares the "online" aspect, its academic domain is vastly different from that of physics and science, which place greater emphasis on conceptual understanding and abstract reasoning (Blegur et al., 2024). Similarly, the study by Hirahmah et al. (2024), which discusses electronic teaching materials for 4C skills in physics, does not specifically address the aspect of assessment (Hirahmah et al., 2024).

This study aims to map and analyze the development of research on e-assessment in physics and science education using a bibliometric approach, thereby providing a comprehensive overview of trends, scientific contributions, and research directions in this field. This research is expected to provide a roadmap for researchers, educators, and policymakers in developing assessment innovations that are more adaptive, personalized, and integrated with cutting-edge technologies such as artificial intelligence (AI), as well as interdisciplinary approaches that bridge assessment and learning. Future research should develop more adaptive and personalized assessment frameworks, integrate emerging technologies, and promote interdisciplinary approaches that bridge assessment and learning (Nurjanah et al., 2025).

METHODS

This study employs a bibliometric approach, which is a quantitative method of analyzing scientific literature aimed at identifying research trends, collaboration patterns, and knowledge structures within a field of study. This approach was chosen because it allows researchers to highlight emerging science and technology, as well as make meaningful and prioritized decisions for future research (Li, Wu, et al., 2024). Bibliometric analysis is a systematic method for exploring large volumes of literature, revealing the nuances of evolution, and identifying research trends in specific topics (Li, Wu, et al., 2024). In the context of this study, the bibliometric approach was used to map publications on e-assessment in physics and science education, identify patterns of scientific collaboration, and identify research gaps that still need to be addressed.

The research design follows the standard protocol for bibliometric analysis, which consists of five main stages: (1) defining the scope and objectives, (2) selecting the analysis techniques, (3) data collection, (4) data analysis, and (5) reporting the results (Li, Wu, et al., 2024). The data sources in this study were derived from the most relevant and comprehensive leading scientific database for the field of physics and science education, namely the Scopus database, in .csv file format. The advantages of the Scopus database include its broad coverage, complete metadata, and inclusion of reference information (Li, Wu, et al., 2024) (Pereira et al., 2025). Data collection was conducted in March 2026. The keywords used in the titles and abstracts are: "e-assessment" OR "online assessment" OR "computer-based assessment" OR "formative assessment" OR "authentic assessment" OR "adaptive assessment" AND "physics education OR science education".

This study employs a combination of bibliometric analysis tools to obtain comprehensive and valid results. This combination is recommended because each tool has specific strengths: a) VOSviewer: VOSviewer is a desktop application used to create and visualize bibliometric networks. The main features to be used include: Co-authorship analysis (authors, institutions, and countries), Keyword co-occurrence analysis, Citation analysis, Bibliographic coupling analysis, Co-citation analysis, Visualization in the form of networks, overlays, and density maps. b) Microsoft Excel, Used for preliminary analysis and the creation of publication graphs.

This study has several limitations that should be acknowledged: a) Database Coverage: This study uses only Scopus as a data source. Although this database is the most comprehensive, the study's results may not fully account for publications indexed only in other databases such as Web of Science, Google Scholar, or Dimensions (Li, Wu, et al., 2024); b) Subject Area: social sciences, physics, and astronomy; c) Language Coverage: Only English-language articles were analyzed, so publications in other languages are not represented (Li, Wang, et al., 2024); d) Document Type: The focus is on journal articles, conference papers, and reviews, so it does not include books or theses (Nurjanah et al., 2025); e) Time Range: The analysis period is limited to the last 10 years (2016–2026), so it does not include earlier literature that may have made significant contributions; f) Limitations of the Method: Bibliometric analysis relies on the availability of consistent metadata from databases; inconsistencies in author names or affiliations may affect the results (Cankara & Cankara, 2025).

The search yielded 190 relevant documents. The data was then exported in CSV format. It was subsequently analyzed using a combination of software: Microsoft Excel for initial analysis and the creation of publication graphs, and VOSviewer for bibliometric analysis and visualization. The frequency of keyword occurrences was limited to a minimum of 3 times, resulting in 51 items and 8 clusters, with 3 main clusters. The analysis results were presented in the form of line charts, pie charts, visual network maps, overlay visualizations, and density visualizations.

RESULTS AND DISCUSSION

Results

Research Trends on E-Assessment in Physics and Science Education

The first finding of this study is an analysis of research trends over the past ten years (2016–2026). This analysis aims to identify growth patterns and dynamics in research on e-assessment in physics and science education. The results are presented in the form of publication trend graphs to facilitate a visual understanding of the changes that have occurred. Thus, the following graph provides an initial overview of the direction of ongoing research.

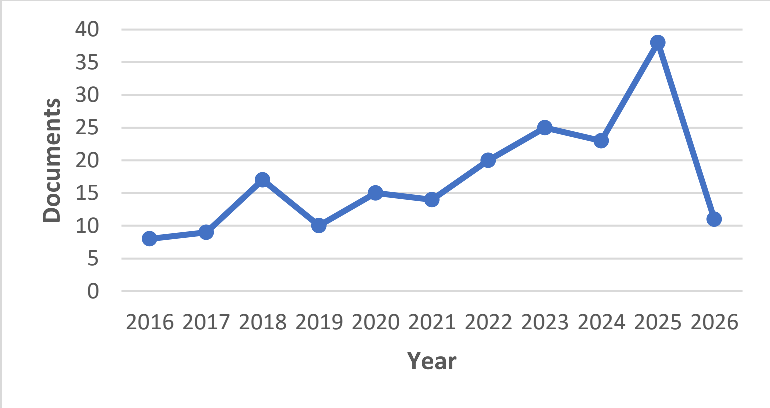

Figure 1. Research Trends on E-Assessment in Physics and Science Education

Figure 1 shows that the number of studies on e-assessment in physics and science education from 2016 to 2026 reveals a very significant upward trend, particularly since 2020, driven by the COVID-19 pandemic, which spurred the rapid adoption of online assessment. During the initial period (2016–2019), the number of publications remained fluctuating, with a peak of 17 in 2018, then surged sharply in 2020 (15) and reached an initial peak in 2021 (14). From 2022 through 2025, the research trend continues to rise exponentially, with the highest surge occurring in 2025 at 38 publications, indicating that e-assessment has transformed from a mere emergency solution into a mature research focus integrated into pedagogical innovation. Although the data shows a projection of only 11 publications for 2026, this is because data collection was conducted in March 2026, and it is predicted to continue increasing until December 2026. Overall, it can be concluded that research in the field of e-assessment within the context of physics and science education is experiencing rapid and sustained growth and is a highly relevant topic for future development, particularly with the integration of technologies such as artificial intelligence and adaptive assessment.

Trends in the Publication of E-Assessment in Physics and Science Education, 2016–2026

The second finding of this study reveals the distribution patterns of publications related to e-assessment in physics and science education during the 2016–2026 period. This analysis includes the identification of the ten countries with the highest number of publications in this field. Additionally, the distribution of publications based on the types of documents used in the research was examined. Furthermore, the distribution of publications by research subject was analyzed to determine the evolving focus of studies in the field of e-assessment. This analysis provides a more comprehensive picture of the characteristics and focus of the research, while also showing how scientific contributions are distributed across various countries, publication types, and fields of study.

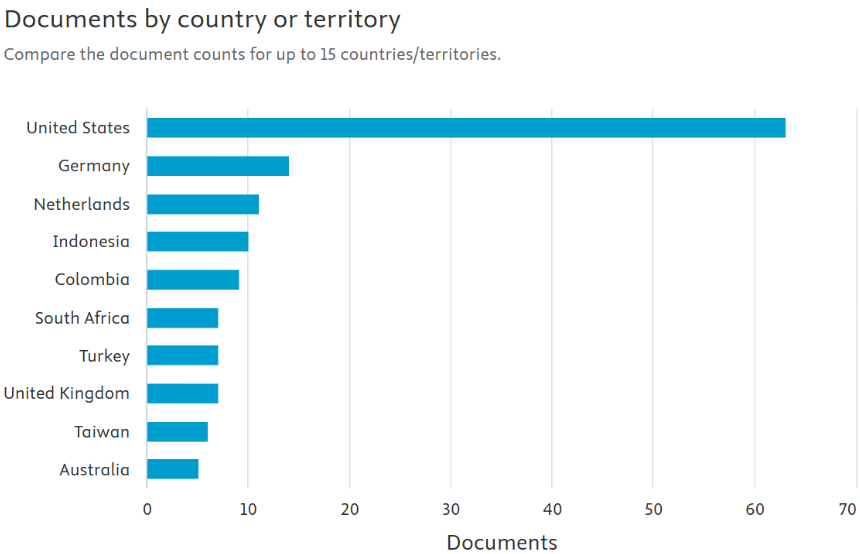

Figure 2. The Ten Countries with the Most Publications on E-Assessment

Figure 2 shows that research on e-assessment in physics education and science education has garnered global attention, with the United States being the leading contributor (accounting for 63 publications), followed by Germany in second place. Indonesia's ranking in fourth place alongside countries such as the Netherlands, Colombia, and South Africa indicates that research on electronic assessment in physics is not only dominated by developed nations but is also rapidly expanding in developing countries. This indicates a growing awareness and effort, particularly in Indonesia, to integrate digital assessment technology into the physics curriculum, although the volume of research still needs to be increased to compete with countries possessing more established research infrastructure.

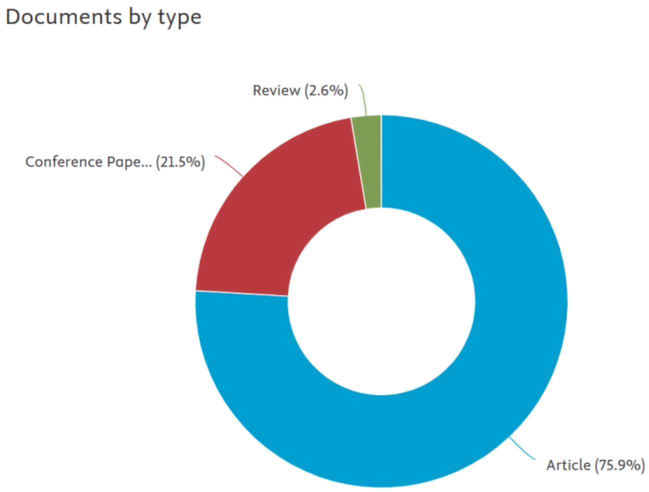

Figure 3. Distribution of E-Assessment Publications by Document Type

Based on the classification of document types (as shown in Figure 3), publications on e-assessment in physics education and learning are dominated by journal articles (75.9%), indicating that the majority of research has undergone a rigorous peer-review process and contributes to the ongoing development of both the theory and practice of digital assessment. The remainder consists of conference papers (21.5%), which reflect the dynamics and latest developments in this field—often first presented in scientific forums—as well as literature reviews (2.6%), which, despite their small number, play a crucial role in summarizing and synthesizing existing knowledge. This composition indicates that the topic of e-assessment in physics has reached a fairly mature stage, where publications are not merely preliminary but have been extensively validated through reputable scientific journals.

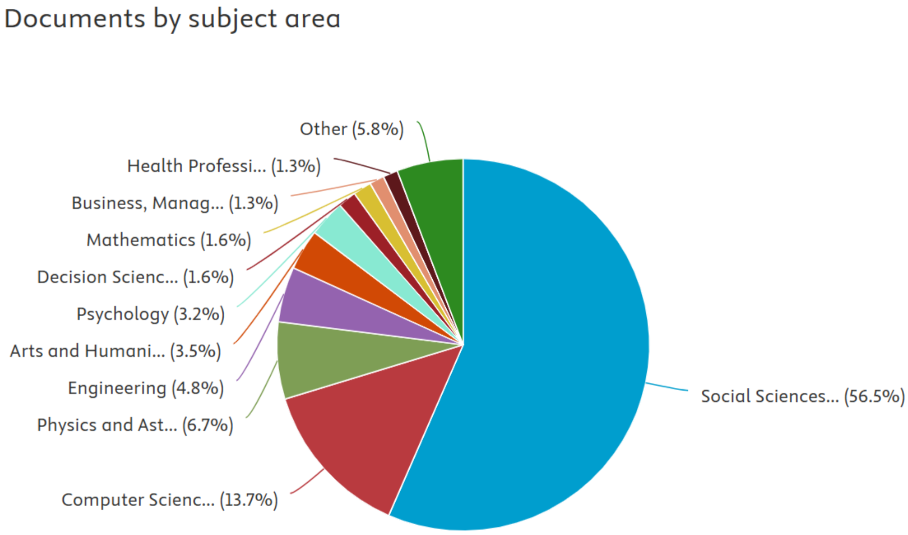

Figure 4. Distribution of E-Assessment Publications by Research Subject

Based on the distribution by subject area (Figure 4), research on e-assessment in physics education contributes most significantly to the Social Sciences (56.5%), confirming that the primary focus of this research is on pedagogical aspects, instructional implementation, and its impact on the teaching-learning process. The Computer Science field (13.7%) ranks second, highlighting the crucial role of system development, digital platforms, and algorithms in supporting the implementation of electronic assessment. Meanwhile, Physics and Astronomy (6.7%) and Engineering (4.8%) have smaller shares, indicating that although the scientific context is physics, publications highlight educational and technological approaches more than pure physics content or technical engineering aspects. The presence of fields such as Arts and Humanities, Psychology, and Decision Sciences also reflects that e-assessment studies in physics are multidisciplinary, touching on cognitive, affective, and decision-making aspects in learning assessment.

Visualization of E-Assessment Research Trend

a. Network Visualization

The third finding of this study pertains to network visualization. This analysis aims to map the relationships among key elements—such as authors, keywords, and documents—within a specific field of study. Through network visualization, patterns of collaboration and the interconnections among research topics can be identified more clearly. Thus, the results of this visualization provide a comprehensive overview of the dynamics and structure of evolving research.

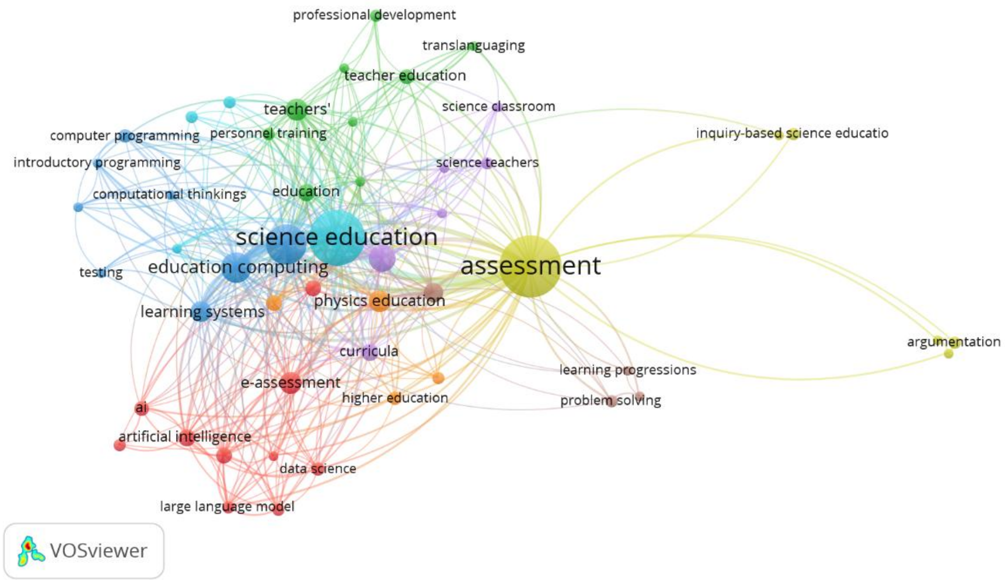

Figure 5. Network Visualization

A bibliometric mapping using VOSviewer of the literature on e-assessment in physics and science education reveals a knowledge structure divided into several major, interrelated thematic clusters. This network visualization indicates that research in this field is no longer focused on a single issue but has evolved toward a more integrative approach, linking assessment technology with innovative pedagogy and essential 21st-century competencies.

The most prominent cluster is the integration of "problem solving" and "learning progressions" into "assessment." This indicates a paradigm shift from traditional assessment, which merely measures final outcomes, toward assessment that serves as a tool for mapping and supporting students' thinking processes on an ongoing basis. Learning progressions provide a robust framework for designing assessments aligned with students' cognitive development in deeply understanding scientific concepts (Jin et al., 2024). Aligning assessment instruments with curriculum objectives and real-world applications is one of the primary research clusters in physics education evaluation (Nurjanah et al., 2025).

The second cluster reveals a strong connection between "data science" and "large language models" (LLMs). The presence of LLMs as a key node indicates that artificial intelligence (AI) is now a primary focus in the development of future assessments. Recent research indicates that multimodal LLMs hold significant potential for handling complex assessment tasks, ranging from evaluating structured exam responses to providing personalized formative feedback (Polverini & Gregorcic, 2025) (Yeadon, 2026). The validity of using LLMs as judges in assessment is largely determined by criterion referenceability that is, the extent to which the assessment task has explicit and observable criteria—which is a key characteristic of learning progression-based assessment (Yeadon, 2026). This opens up opportunities to develop adaptive assessment systems that are not only efficient but also highly accurate in diagnosing student learning progress.

The third cluster links "physics education" and "science education" with 'curricula' and "problem solving." This relationship highlights the importance of developing curricula integrated with authentic assessment to foster 21st-century skills. The integration of the

Problem-Based Learning (PBL) model into electronic modules (e-modules) is a promising research trend for enhancing students' problem-solving abilities, which is one of the primary goals of modern curricula (Wiska et al., 2025). Online assessment provides an opportunity for teachers to develop more objective and credible technology-based assessment skills, although the challenges in its implementation still need to be further explored (Blegur et al., 2024).

Overall, this research network map confirms that e-assessment research in physics and science is moving toward a convergence between technological innovations (AI, data science) and a strong pedagogical foundation (learning progressions, problem solving). Future research is likely to focus on the development of personalized and adaptive assessment frameworks that leverage artificial intelligence to provide real-time formative feedback, while remaining grounded in robust learning development theories to ensure pedagogical effectiveness (Nurjanah et al., 2025).

b. Overlay Visualization

The fourth finding of this study pertains to overlay visualization. This visualization aims to examine temporal developments in the research under study. It enables the identification of trends over time, revealing which topics were studied earlier and which are more recent. By utilizing color gradients, overlay visualization provides insights into the dynamics of the emergence and evolution of a research topic. Therefore, the results of this visualization are crucial for understanding the direction of development and current trends in the analyzed field.

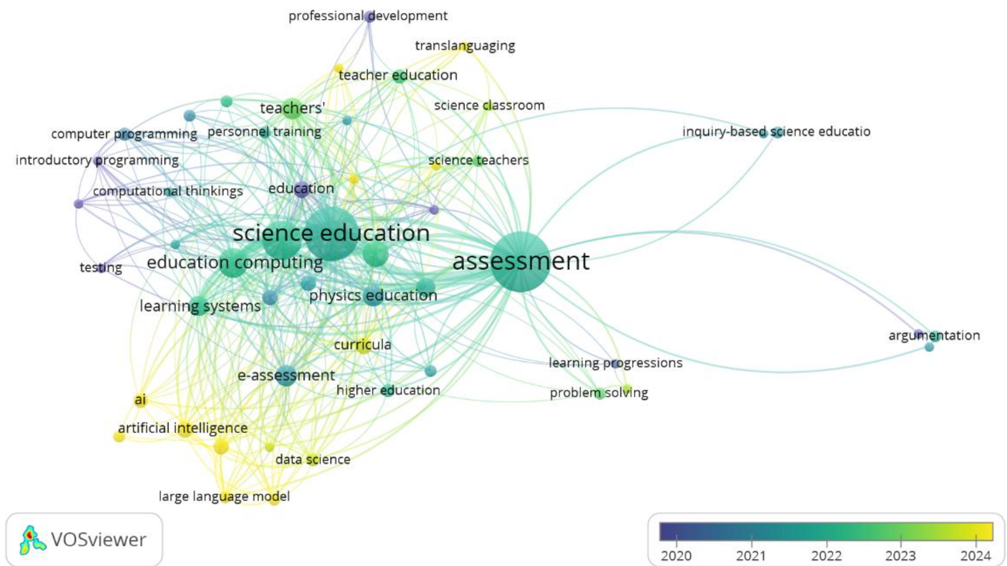

Figure 6. Overlay Visualization

Overlay visualization analysis using VOSviewer provides a crucial temporal dimension in the bibliometric mapping of e-assessment research in the fields of physics and science education. This visualization clearly illustrates shifts in research focus over time, revealing the most dynamic current trends and future directions in this domain. Nodes displayed in lighter colors (indicating more recent emergence or increased significance) suggest that the current focus of research is shifting toward the integration of cutting-edge technology and 21st-century competencies.

The most notable finding from this overlay is the identification of "large language models" (LLMs) and "data science" as the most cutting-edge research areas. The presence of LLMs as the brightest node confirms that generative artificial intelligence has become a game-changer in the discourse on educational assessment. Recent research indicates that educators and researchers are currently exploring how LLMs can be ethically and effectively integrated into the assessment process. A qualitative study published in the Harvard Data Science Review in 2026 revealed that more than half of data science instructors have begun adapting their teaching and assessment methods by leveraging LLMs, both as tutorial tools and in designing "AI-aware" assignments (Wang, 2026). Furthermore, collaborative research presented at the European Conference on Educational Research (ECER) 2025 has even formulated design principles for assessment tasks that allow access to LLMs, focusing on the development of competencies such as effective prompt formulation, critical evaluation of AI outputs, and strategic problem-solving prior to interacting with AI (Eyal, 2025).

At the same time, the concept of "problem solving" continues to demonstrate its relevance, though it is now closely linked to a more structured and atomistic approach to digital assessment. The latest trends indicate a shift from assessing final outcomes (product) toward assessing the process (process). Research by Meyer and Friege (2026), published in Frontiers in Education, introduces an "atomized" approach to assessing physics problem-solving skills. This approach breaks down the problem-solving process into distinct sub-processes—Representation, Planning, Execution, and Evaluation—each of which is assessed independently within a digital environment (Meyer & Friege, 2026). This enables a more precise identification of the specific points of difficulty students encounter, a significant advancement over traditional assessment methods. These findings align with a trend analysis conducted by Le et al. (2025), who, in their bibliometric study, identified that learning analytics and virtual laboratories are emerging research themes in online physics education, indicating a shift toward more technology-driven and data-centered learning and assessment methods (Le et al., 2025).

Another cluster showing development is "higher education" and "curricula." The relatively lighter colour of these nodes indicates that discussions on e-assessment are increasingly focused on how technology—particularly AI—is driving curriculum reform in higher education. Recent literature highlights that adapting curricula and assessments to the presence of AI is no longer merely an option, but a necessity. A 2024 book published by Springer, Digital Assessment in Higher Education, explicitly addresses this wave of change, highlighting ongoing trends and new challenges in digital assessment in the AI era, including how assessment frameworks must be redesigned to accommodate tools like ChatGPT while upholding academic integrity and fostering higher-order thinking skills (Grosseck, 2024).

Overall, this visualization highlights that research on e-assessment in physics and science is at a critical turning point. While past research focused on the basic application of digital technology for assessment, current and future directions are dominated by efforts to intelligently integrate artificial intelligence and data analytics into a robust pedagogical framework. The focus has shifted from merely "assessing with technology" to "assessing competencies in the technological era," which demands fundamental changes in curriculum design, the development of process-based assessment instruments, and the enhancement of digital and AI literacy for educators and students.

c. Density Visualization

The fifth finding in this study pertains to density visualization. This visualization aims to illustrate the density and frequency of occurrence of a particular element in the research. It helps identify the areas or topics most frequently studied based on the concentration of data displayed. The higher the density of an area, the greater the attention researchers have paid to that topic. Thus, density visualization provides a clear picture of the main focus and dominance of themes within the field of study being analyzed.

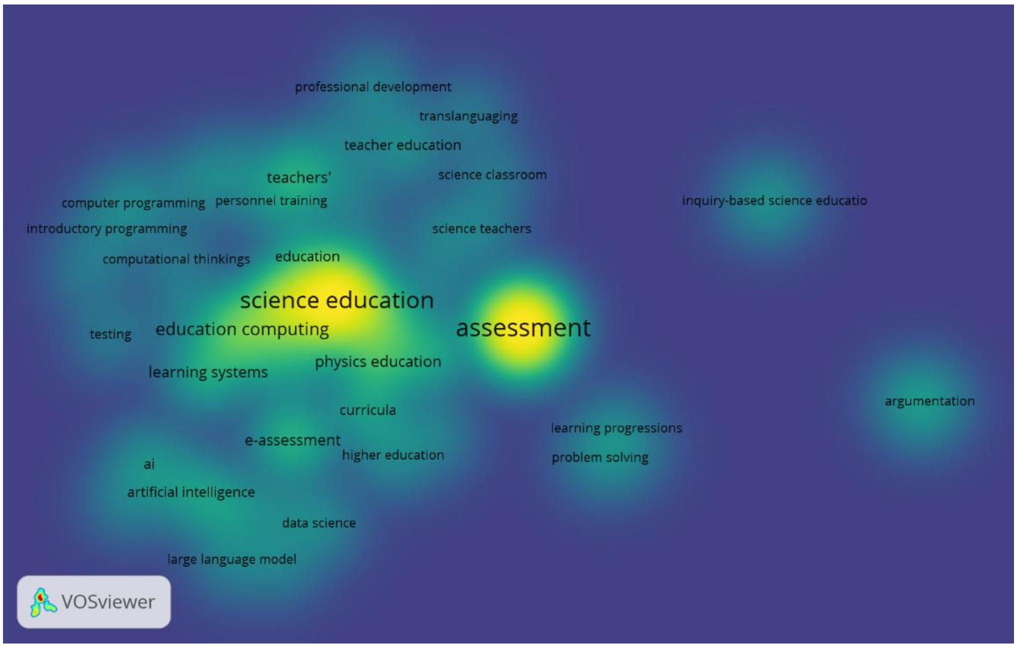

Figure 7. Density Visualization

Density visualization analysis using VOSviewer provides the most comprehensive mapping of the knowledge structure of e-assessment research in the fields of physics and science education, with areas of high density indicating well-established topics that are the primary focus of the literature. This visualization reveals that research in this field is no longer centered on one or two dominant themes but has evolved into a rich research ecosystem with several interconnected centers of density, reflecting the complexity and maturity of this field of study.

The highest density was observed in the "science education," "assessment," and "physics education" clusters, followed by strong density in "problem solving" and "curricula." This confirms that electronic assessment has become an integral part of core discussions in science and physics education, with problem solving as a key competency that continues to be a focus of attention. These findings align with the bibliometric analysis conducted by Le et al. (2025), which identified that the integration of learning analytics and virtual laboratories is an emerging research theme in online physics education, indicating a shift toward more technology-driven and data-centered learning and assessment methods (Le et al., 2025). Research by Meyer and Friege (2026) further reinforces these findings by introducing an "atomized" approach to assessing physics problem-solving skills, which breaks down the problem-solving process into separate sub-processes assessed independently in a digital environment, allowing for more precise identification of specific difficulty points experienced by students (Le et al., 2025).

Significant density is also evident in the areas of "educational computing" and "learning systems," indicating that the technological infrastructure supporting assessment has become a well-established foundation. However, what is more intriguing is the emergence of areas showing increasing density, though not yet as high as the core clusters, such as "artificial intelligence," "large language models," "data science," and "computational thinking." The presence of artificial intelligence and large language models as areas showing increasing density underscores that generative artificial intelligence has become a game-changer in the discourse on educational assessment (Lehtonen, 2025). Research by Yeadon et al. (2026) indicates that the validity of using LLMs as evaluators (judges) in assessment is highly dependent on criterion-reference ability, aligning with the need for assessments that have explicit and observable criteria (Lehtonen, 2025). Meanwhile, the development of online assessment instruments to measure computational thinking and algebraic thinking has been widely undertaken, such as the COMATH project involving more than 3,000 students from six countries, demonstrating global attention to these 21st-century competencies (Lehtonen, 2025).

Equally important is the emergence of areas with distinct concentrations in the clusters of "translanguaging," "teacher development," "teacher education," and "inquiry-based science education." The presence of translanguaging as a notably concentrated area is a particularly intriguing finding, as it indicates a paradigm shift toward more inclusive and equitable assessment approaches. Recent research confirms that science assessment, which has long been dominated by the use of English alone, fails to provide a complete picture of multilingual students' knowledge. Fine and Furtak (2025), in an article in the *Journal of Research in Science Teaching*, call for reimagining the science formative assessment system by integrating translanguaging, which allows students to use their entire semiotic repertoire—both linguistic and non-linguistic—to communicate scientific ideas (Fine & Furtak, 2025) (Fine et al., 2025). This study by Fine and Furtak shows that sixth-grade students have insightful and nuanced views on translanguaging, seeing it as a practice that supports their English language development while allowing them to focus bilingually on scientific ideas without having to translate everything into English (Fine et al., 2025). This calls for structural and policy changes in the assessment system to authentically center translanguaging as an equity-oriented practice ((Fine & Furtak, 2025).

Overall, this density visualization confirms that e-assessment research in physics and science has reached a level of maturity, as evidenced by the presence of several interconnected major clusters. Future research directions point toward a convergence between cutting-edge technological innovations (AI, LLM, data science) and inclusive, equitable pedagogical approaches (translanguaging, inquiry-based assessment), as well as teacher professional development (teacher education), which are key to successful implementation. These findings indicate that the future assessment paradigm will be evaluated not only based on the accuracy of competency measurement but also on its ability to accommodate the linguistic, cultural, and cognitive diversity of students in the digital age.

CONCLUSION

This study shows that research on electronic assessment in physics and science education has experienced rapid growth, particularly since 2020 as a result of the COVID-19 pandemic, which accelerated the adoption of digital technology in education. The United States has been the primary contributor, while Indonesia, along with several other developing countries, has also begun to show significant interest in this topic, indicating a global awareness of the importance of digital transformation in educational assessment. Key findings from this mapping reveal that the focus of research has shifted from merely applying digital technology for assessment toward integrating artificial intelligence and large language models in designing adaptive, personalized assessments that focus on students' thinking processes. Furthermore, new approaches such as atomized problem-solving and the use of translanguaging in assessment indicate that the future direction of assessment development demands not only the accuracy of competency measurement but also the ability to accommodate learners' cognitive, linguistic, and cultural diversity. Thus, the main contribution of this research is to provide a roadmap showing that assessment innovation in the digital age needs to combine technological advancements with a strong pedagogical foundation as well as inclusive and equitable approaches.

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