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Integrating PBL, Ethno-STEM, and AR for Critical Thinking and Digital Literacy: A Systematic Review (2016–2025)

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Abstract: This study aims to describe research trends related to the integration of Problem-Based Learning (PBL), Ethno-STEM, and Augmented Reality (AR) in improving students' critical thinking skills and digital literacy during the period 2016 to 2025. The formulation of the problem in this study is how the development of scientific publications related to the integration of the three approaches and their contribution to strengthening 21st century skills. The method used is descriptive analysis with a bibliometric approach using data from Google Scholar analyzed through Publish or Perish (PoP), Dimensions.ai, and visualized using VOSviewer. The results of the study show a significant increasing trend in publications discussing the integration of PBL, Ethno-STEM, and AR, especially since 2022, as well as the dominance of publications in the form of book chapters. In addition, keyword visualization confirms that the theme of developing innovative learning models, critical thinking, and digital literacy is the main focus in modern science education research. This study recommends further development of the integration of contextual and technological approaches to support improving the quality of learning in the digital era.

Keywords: Augmented Reality; Critical Thinking; Digital Literacy; Ethno-STEM; Problem-Based Learning

Introduction

The development of technology and science requires students to have 21st century skills, such as critical thinking skills and digital literacy. Critical thinking skills are very important for students to be able to analyze, evaluate, and solve problems logically and systematically. Meanwhile, digital literacy is a basic need in facing the increasingly complex digital era, where students must be able to access, evaluate, and use information effectively and ethically. Based on an analysis of several relevant journals, there are several problems faced in science learning at the junior high school level. First, the learning method that is still dominated by teachers (teacher-centered) causes students to be less actively involved in the learning process, so that their critical thinking skills do not develop optimally (Adhelacahya, Sukarmin, and Sarwanto 2023). Second, the lack of use of technology in learning causes low digital literacy of students, which is indicated by their inability to access and evaluate information critically (Pamorti, Winarno, and Suryandari 2024). Third, science learning is often considered abstract and irrelevant to everyday life, so students are less motivated to learn it (Sumarni and Kadarwati 2020).

Previous studies have shown that learning approaches that emphasize interactivity and local cultural context can improve students' motivation and understanding, as evidenced by Adhelacahya et al. (2023) and Sumarni & Kadarwati (2020). In addition, the integration of AR technology in learning has been shown to be effective in visualizing abstract concepts, supporting more engaging learning experiences, and improving students' digital skills, in accordance with the findings by Prananta et al. (2024). Previous research states that digital teaching materials containing Ethno-STEM content are effective in improving the science literacy of fourth grade elementary school students (Juniawan, Sumarni, and Prasetya 2024).

The Ethno-STEM approach allows students to learn science concepts through local cultural contexts, making learning more meaningful and relevant to everyday life. The use of AR as a learning medium can increase the interactivity and visualization of materials, making it easier for students to understand abstract

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concepts. By combining PBL, Ethno-STEM, and AR, it is hoped that it can create a learning environment that encourages students to think critically and improve digital literacy.

Research on PBL (Ruliyanti, Harjono, and Rahayu 2020) is quite popular and shows a high publication trend (Napitupulu, Hutahaean, and Fauziyyah 2024); (Miranti, Harjono, and Rahayu 2022). Previous research shows that the use of PBL-based learning modules and STEM approaches can improve students' critical thinking skills (Han et al. 2016); (Umam and Susandi 2022); (Rahayu and Al Hadi 2023); (Afikah, Rohaeti, and Jumadi 2024). The implications of e-book products based on local wisdom integrated with STEAM and SDGs that are developed practically can be used by teachers in learning to train students' critical thinking skills and digital literacy (Rahayu et al., 2025). However, the integration of local culture/Ethno-STEM (Rahmat et al. 2023) and AR technology in learning modules is still rare (Muktiani et al. 2022), especially in measuring digital literacy (Adriana et al. 2024); (Choi et al. 2023); (Techataweewan and Prasertsin 2018); (Utami, Apriliya, and Saputra 2022). This can make learning more contextual and interesting for students.

Most of the articles emphasize the importance of project-based learning methods and local cultural integration (Minardi et al. 2024) to improve students' critical thinking skills (Rahayu and Artayasa 2025); (Bramastia and Rahayu 2023). In addition, articles on the use of AR in learning (Prahanı, Saphıra, and Wıbowo 2022); (Prananta et al. 2024) provide evidence that technology can enrich the learning experience and improve understanding of abstract concepts. The development of teaching materials (Sutrio, Rokhmat, and Rahayu 2021) in the form of modules that combine PBL, Ethno-STEM, and AR is very relevant and has the potential to provide innovative solutions in improving students' critical thinking skills and digital literacy. Therefore, this research wants to know the research trends on the integration of Problem Based Learning, Ethno-STEM, and Augmented Reality for improving students' Critical Thinking and Digital Literacy. The researcher hopes that this research can be useful and become a reference in the future in developing further research related to the integration of problem-based learning, ethno-STEM, augmented reality, to improve critical thinking skills and digital literacy.

Method

This research method uses a descriptive analysis method, which functions to determine and describe research trends from the integration of problem-based learning, ethno-STEM, and augmented reality to improve students' critical thinking skills and digital literacy. The data used in this study contains information sourced from Google Scholar using analytical tools such as Publish or Perish (PoP) and Dimension.ai. The keywords used are problem-based learning, ethno-STEM, augmented reality, critical thinking skills and digital literacy.

In this study, analyzing data from 1000 documents indexed by Google Scholar. Google Scholar has strict standards in selecting documents so that researchers choose to use data from Google Scholar. In addition to processing the data using PoP and Dimension.ai, researchers also use VosViewer as a tool to view the network, overlay and density of the distribution of previously searched keywords. The methods used include quantitative analysis using VOSviewer software to visualize data and qualitative content analysis for interpretation of text data.

Result and Discussion

This study aims to describe research trends from the integration of problem-based learning, ethno-STEM, augmented reality, to improve critical thinking and digital literacy from 2016 to 2025. This study analyzes the trend graph of keyword publications, publication type trends, top 10 sources titles, top 10 citations and keywords on trend. The trend is analyzed using Dimensions.ai. In addition, data from Google Scholar that has been processed using PoP, is analyzed using VosViewer. There are 3 things analyzed, namely, network visualization graphs, overlay visualization, and density visualization.

Previous research has shown that STEM-PBL as an inquiry approach has been shown to improve student achievement in Biology (Usman, Ali, and Ahmad 2023). In addition, previously research has been conducted on the trends of digital literacy publications in education indexed in the Scopus database from 2015 to 2024, with a focus on publication growth, country contributions, and dominant fields of study (Adriana et al. 2024). Another study analyzed the influence of self-management skills, consisting of self-motivation, self-organization, and self-control, on students' digital literacy (Ririen and Heriasman 2021). There is also research that analyzes prospective teachers' perceptions of critical thinking skills and changes in these perceptions over a four-year period (Özelçi and Çalışkan 2019).

Other studies indicate that the application of hypothetico-deductive schemes can improve students' understanding of quantum theory and develop their critical thinking skills (Tereshchuk et al. 2023). In addition, previous research has raised the issue of low critical thinking skills of students, which is assessed through the use of essay test instruments with CT

rubrics (Suciati et al. 2022). The influence of conventional learning models, Problem-Based Learning (PBL), Numbered-Head Together (NHT), and integrated NHT-PBL on the critical thinking skills of students with low and high academic abilities has also been studied previously (Rijal et al. 2021).

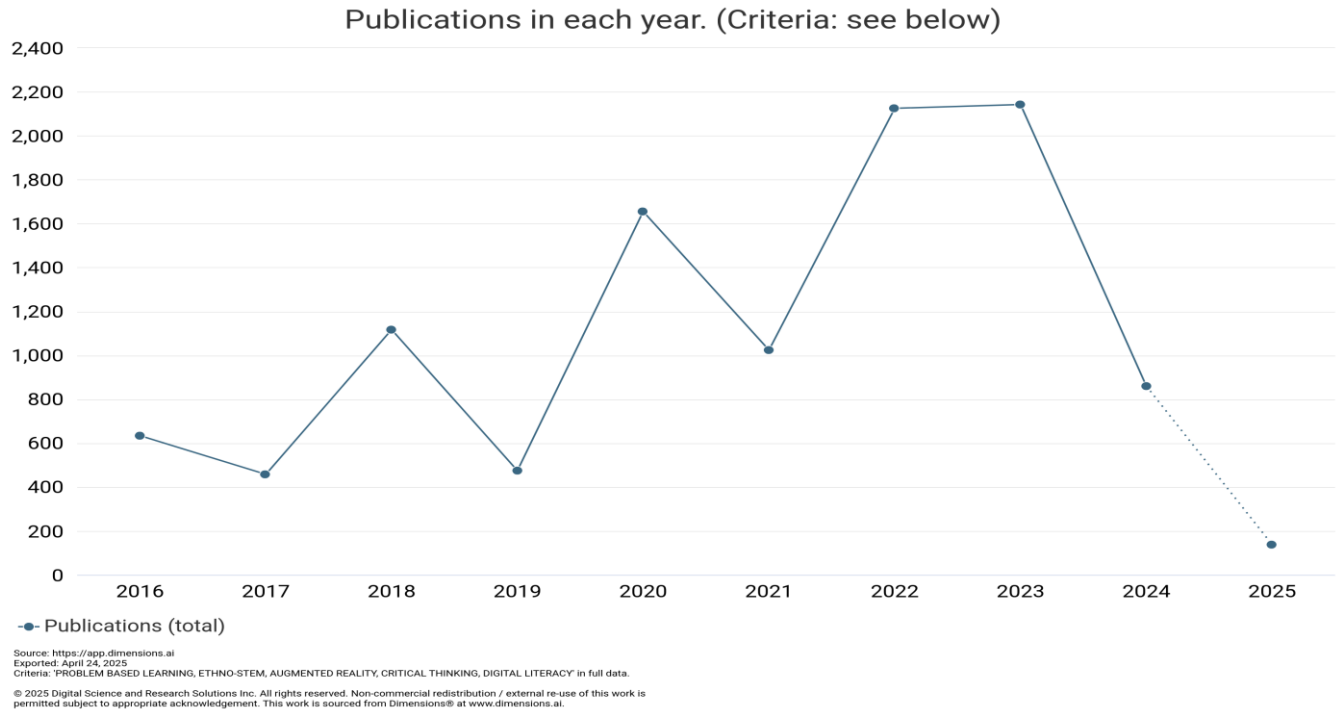

Figure 1. Research Trends in Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking and Digital Literacy

In addition, the analysis of the influence of science process skills on students' critical thinking skills in secondary schools, taking into account the differences between students in urban and rural areas, has also been studied (Darmaji et al. 2020). STEM can improve academic achievement and encourage student interest in STEM fields (Han et al. 2016). Previous research findings indicate a positive relationship between student-focused teaching approaches and academic achievement, as well as between PBL and academic achievement (Bara and Xhomara 2020). Integration of TPS and PBL methods can be effective in improving students' critical thinking skills (Muhfahroyin et al. 2023). Other studies have shown that the application of modern technology can improve students' critical thinking and information literacy skills (Hongphanut 2023). DMRL (Discovery-Based Multiple Representations Learning) model can be optimized to improve students' critical thinking skills on environmental change material as an alternative effective learning model (Chusni 2023).

Research on the development of problem-based learning (PBL) models in biology education courses and evaluating the feasibility of the developed models has been previously studied (Aryulina and Riyanto 2016). The development of an instrument to measure digital skills literacy among college students has been studied, providing insights for educators and policy makers in developing more effective digital literacy programs (Harlanu et al. 2023). Other findings also indicate that educators' digital literacy competencies are important for improving lecturers' digital literacy competencies to promote the quality of online course design (Stefany and Helmi 2024).

Another finding emphasizes the importance of developing digital literacy competencies among prospective teachers to improve the quality of learning in the digital era (Rusydiyah, Purwati, and Prabowo 2020). There are also findings about the importance of implementing PBL in higher education, especially in fields that require practical skills such as physical therapy (Kushartanti 2010). Findings on AR demonstrate the potential of AR technology in improving the quality of biology learning, while highlighting the need for further development to overcome existing technical limitations (Qumillaila, Susanti, and Zulfiani 2017). Another finding highlights the importance of implementing the OLS-CMPBL model as an alternative in learning to improve students' digital skills (Perdana et al. 2020).

Based on publication data from Dimensions.ai from 2016 to 2025 as shown in Figure 1, there is a significant fluctuation in the trend of the number of publications each year. In 2016, the number of

publications was recorded at 634 articles, but decreased to 458 the following year. Interestingly, in 2018 there was a sharp spike to 1,117 publications before dropping drastically to 475 in 2019. The first peak occurred in 2020 with a total of 1,655 publications—most likely influenced by the increasing need for innovation and research during the COVID-19 pandemic which encouraged the adoption of educational technology and new learning methods such as Problem Based Learning (PBL), Ethno-STEM, and Augmented Reality.

After that peak, although it dropped to 1,024 in the following year (2021), the trend again showed a significant increase with two consecutive highest peaks in 2022 and 2023, namely 2,125 and 2,142 publications, respectively—indicating a very high research interest in topics related to digital literacy and critical thinking in technology-based education and its integration with the STEM ethnopedagogy approach.

However, after this peak period there is a sharp decline; in 2024 there were only 860 publications, and this decline further to 138 in early or mid-2025 (data may not be complete for a full year). Overall, this pattern suggests that research interest in innovative themes in education has increased rapidly over the past few years before leveling off over time or with changes in the focus of recent global research. Furthermore, based on data from Dimensions.ai regarding publication types, trends in Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy, the results are as shown in Table 1.

Table 1. Trends in Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy Based on Publication Types

Publication Type	Publications
Chapter	8209
Edited Book	4191
Monograph	1585
Article	517
Proceeding	262
Preprint	13

Based on data from Dimensions.ai presented in Table 1, it can be seen that publications related to Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy are mostly found in the form of book chapters with a total of 8,209 publications. This number far exceeds other types of publications such as edited books with 4,191 and monographs with 1,585 documents. Meanwhile, there are only 517 journal articles and 262 conference proceedings, indicating that these topics are more often discussed in depth in books or collections of scientific writings than published as journal articles or conference proceedings. As for preprints, very few were found, namely only 13 documents, indicating that the initial dissemination of research results in this field is still minimal before the formal peer-review process is carried out. Overall, this distribution indicates that the development of science on innovative educational themes tends to be expressed through book-based writings that are collaborative and comprehensive compared to other conventional scientific publication media.

Table 2. Top 20 Sources Title Trend of Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy in 2016-2025

Name	Publications	Citations	Citations Mean
Bulletin of the LN Gumilyov Eurasian National University Pedagogy Psychology Sociology Series	216	7	0.03
Lecture Notes in Computer Science	58	320	5.52
Encyclopedia of the UN Sustainable Development Goals	49	162	3.31
Journal of the Royal Anthropological Institute	42	11	0.26
Lecture Notes in Networks and Systems	40	131	3.28
NWU Self-Directed Learning Series	38	44	1.16
Advances in Social Science, Education and Humanities Research	37	31	0.84
The Statesman's Yearbook	23	42	1.83
Abstracts in Anthropology	23	1	0.04
Reformed Theology in Africa Series	20	10	0.50
Knowledge Pathing: Multi-, Inter- and Trans-Disciplining in Social Sciences Series	17	5	0.29
Jurnal Penelitian Pendidikan IPA	15	20	1.33
Advances in Intelligent Systems and Computing	14	53	3.79
Communications in Computer and Information Science	14	86	6.14
Springer International Handbooks of Education	14	470	33.57
Springer Proceedings in Business and Economics	13	48	3.69
SSRN Electronic Journal	12	84	7.00
Integration of Education	11	35	3.18
Handbooks of Sociology and Social Research	9	313	34.78
Sustainable Development Goals Series	9	15	1.67

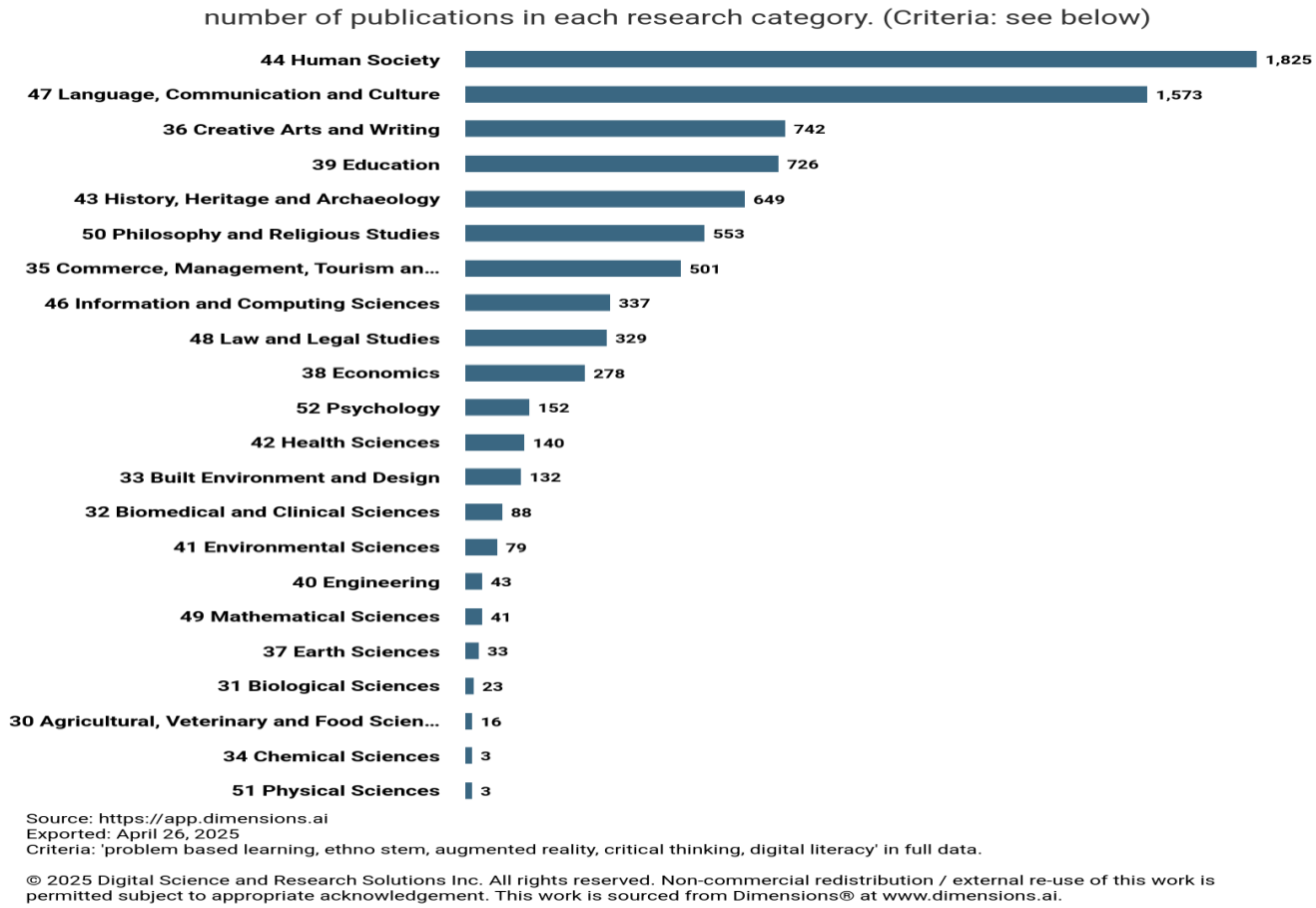

Figure 2. Research categories based on the classification of Fields of Research (ANZSRC 2020)

Based on Table 2, which contains the top 20 publication sources related to Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy in the period 2016-2025, there is a significant difference between the number of publications and their citation impact. Bulletin of the LN Gumilyov Eurasian National University Pedagogy Psychology Sociology Series has the highest number of publications of 216 articles but with a very low average citation (0.03), while sources such as Springer International Handbooks of Education and Handbooks of Sociology and Social Research, although only publishing a few articles (14 and 9), have a very high average citation of over 30 per article, indicating high scientific quality and influence. In addition, technology-based journals such as Lecture Notes in Computer Science, Communications in Computer and Information Science, and SSRN Electronic Journal also performed well with an average citation of between 5 and 7 per article despite their medium to low publication volume. This reflects that research in the field of innovative education is not only widely published in various types of sources but also receives varying academic attention depending on the quality and relevance of each publication medium.

Based on the research field category data according to ANZSRC 2020, which can be searched using Dimensions.ai (Figure 2), it can be seen that the Human Society field dominates with a total of 1,825 publications, indicating a large focus on social studies in the context of research related to Problem Based Learning, Ethno-STEM, and digital literacy. Within it, subfields such as Political Science (498) and Policy and Administration (215) occupy the top positions, indicating significant attention to policy and governance aspects in education and community development. In addition, the Language, Communication and Culture field is also very prominent with 1,573 publications; especially subfields such as Cultural Studies (676) and Communication and Media Studies (262) which reflect the importance of cultural and media communication as part of the innovative learning process. Other fields such as Sociology, Human Geography, and Gender Studies also make significant contributions to this research. Overall, this data illustrates that research in the area of innovative education does not only focus on technical or pedagogical aspects but also pays attention to socio-cultural and policy dimensions that influence its implementation broadly.

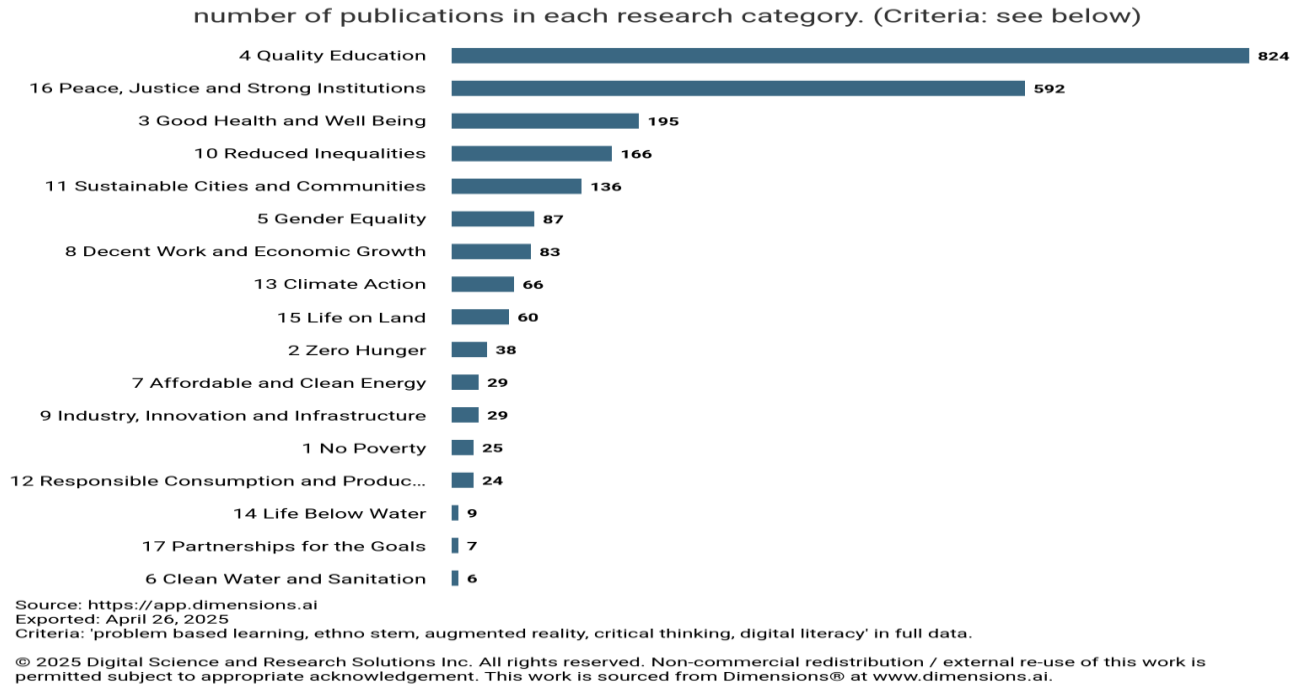

Figure 3. Research categories based on the classification of Sustainable Development Goals (SDGs)

Based on publication classification data according to the Sustainable Development Goals (SDGs) category (Figure 3), it can be seen that the most dominant research focus is on Goal 4: Quality Education with the number of publications reaching 824, indicating great attention to improving the quality of education in the context of research related to Problem Based Learning, Ethno-STEM, and educational technology. Furthermore, the category of Goal 16: Peace, Justice and Strong Institutions also occupies an important position with 592 publications, indicating that there is a link between research and institutional aspects and social justice. Other categories such as Good Health and Well Being (195) and Reduced Inequalities (166) also receive significant attention although the number is smaller than the two main priorities. Meanwhile, several SDGs such as Clean Water and Sanitation, Partnerships for the Goals, and Life Below Water have a very low number of publications (<10), indicating that these topics are less of a focus in research related to innovative education and digital literacy themes during the observation period. Overall, this distribution reflects a strong research orientation on developing the quality of education as the main foundation for achieving other sustainable development goals.

Table 3. Top 10 Citations/Year on Trend of Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy in 2016-2025

Cites/Year	Year	Author	Title
5452.67	2019	M Hammersley, P Atkinson	Ethnography: Principles in practice
643.00	2023	S Helmreich	Alien ocean: Anthropological voyages in microbial seas
520.00	2023	G Born	Rationalizing culture: IRCAM, Boulez, and the institutionalization of the musical avant-garde
217.33	2022	L Holbeche	Aligning human resources and business strategy
185.29	2018	R Sharpley	Tourism, tourists and society
156.17	2019	A Hepp	Deep mediatization
104.00	2024	EG Arias	The Meaning and use of Housing: international perspectives, approaches and their applications
88.33	2019	L Hjorth, S Hinton	Understanding social media
87.00	2024	TTS Strat, EK Henriksen, KM Jegstad	Inquiry-based science education in science teacher education: a systematic review
86.00	2024	M Turan	Vernacular architecture: paradigms of environmental response

Based on data obtained from 1000 Google Scholar journal articles using Publish or Perish (PoP) listed in Table 3 which displays the 10 publications with the highest citations per year in the trends of Problem

Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy during the period 2016-2025, it can be seen that the work of M. Hammersley and P. Atkinson (2019) entitled Ethnography: Principles in Practice dominates with very high citations reaching an average of 5,452.67 citations per year, indicating a major influence in the field of ethnography relevant to the ethno-STEM approach. In addition, several recent publications from 2023 and 2024 also show significant citation rates such as the works of S. Helmreich (Alien Ocean) and G. Born (Rationalizing Culture) each with more than 500 citations per year, indicating a strong interest in the study of cultural anthropology and institutional innovation in the context of education and digital technology. Other works such as Aligning Human Resources and Business Strategy (2022) and articles related to social media and vernacular architecture also received considerable attention although with lower citation rates in the range of tens to hundreds per year. Overall, these data illustrate that key research that contributes to the development of the theme of problem-based learning and its integration with cultural and technological aspects has had a very significant scientific impact on the global academic community over the past decade.

Table 4. Top 10 Trends of Researchers Researching Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy in 2016-2025

Name Organization, Country	Publications	Citations	Citations Mean
Roger J R Levesque Indiana University Bloomington, United States	46	6	0.13
Iztok Podbregar University of Maribor, Slovenia	38	6	0.16
Alex C Michalos University of Northern British Columbia, Canada	30	6	0.20
- North-West University	20	30	1.50
Daniel T L Shek Hong Kong Polytechnic University, China	19	25	1.32
Christopher L Atkinson University of Social Sciences and Humanities, Poland	17	1	0.06
Jeremy Tambling University of Social Sciences and Humanities, Poland	17	0	-
Mario Coccia Nasional Research Council, Italy	15	4	0.27
Dorian Q Fuller University College London, United Kongdom	15	107	7.13
Ikechukwu Ogeze Ukeje Alex Ekwueme Federal University Ndufu-Alike, Nigeria	14	1	0.07

Based on data from Dimensions.ai regarding research trends related to Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy in the period 2016-2025, it can be seen that Roger J R Levesque from Indiana University Bloomington leads with the largest number of publications of 46 works despite having a low average citation of 0.13. Iztok Podbregar and Alex C Michalos also showed significant contributions with 38 and 30 publications respectively and slightly higher average citations (0.16 and 0.20). Interestingly, North-West University has fewer publications (20) but gets much more total citations (30) with an average citation per publication reaching 1.50, indicating a greater quality or influence of research compared to several other researchers with more works. Daniel T L Shek from Hong Kong Polytechnic University also showed similar performance with a high citation ratio (1.32). Meanwhile, Dorian Q Fuller from University College London stands out significantly in terms of research impact despite publishing only 15 works but obtaining a very high total citation of 107, resulting in the highest average citation of 7.13 per publication. This data illustrates the variation between the quantity and quality of research in the field across global institutions over the past decade.

Table 5 presents the analysis of trending keywords in the context of Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy based on publication type, focusing on the frequency of occurrence and relevance of each term. From the data, it can be seen that terms such as "Physics" and "Science Education" have the highest frequency of occurrence of 34 and 31 times respectively, although their relevance is at a base value of 1.00, indicating that these two terms are common

and fundamental topics in the analyzed literature. Meanwhile, the terms "Local Wisdom" and "Ethnoscience" also show significant frequencies, 32 and 29 times respectively, with quite high relevance (1.36 and 1.75), indicating the importance of integrating local wisdom and ethnoscience approaches in developing contextual and cultural STEM-based learning models.

Table 5. Keywords on Trend Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy Based on Publication Types

Terms	Occurences	Relevance
Critical Literacy	12	1.75
Ethnoscience	29	1.75
E-Module	27	1.55
Critical Thinking	28	1.41
Local Wisdom	32	1.36
Digital Literacy	12	1.17
21st Century	13	1.07
Cultural Study	12	1.06
Physics	34	1.00
Science Education	31	1.00

The terms “Critical Literacy” and “Critical Thinking” despite having lower frequencies (12 and 28), show quite high relevance (1.75 and 1.41), indicating a strong focus on developing critical thinking skills and critical literacy in the context of 21st century education. In addition, the terms "E-Module" and "Digital Literacy" also appear with quite significant frequency (27 and 12) and supporting relevance (1.55 and 1.17), which reflects the trend of utilizing digital technology and electronic modules in the modern learning process. Overall, this table illustrates the close relationship between cultural aspects, technology, and critical thinking skills in contemporary educational research oriented towards developing 21st century competencies.

The keyword network visualization image in Figure 4 shows four main clusters representing research themes in education and literacy based on the analysis of 1000 Google Scholar journals using VOSviewer. The blue cluster highlights science disciplines such as biology, chemistry, physics, mathematics, and science education as the main focus of science education research. The green cluster is related to the development of project-based learning models and the improvement of critical thinking skills and learning effectiveness. These two clusters are closely related because the learning models developed aim to improve the understanding of basic science concepts.

Meanwhile, the red cluster focuses on language practices, digital literacy, and learning guides that demonstrate the application of knowledge in real contexts and the use of digital technology in the teaching and learning process. The yellow cluster connects training with learning motivation and foreign language proficiency through the support of information and communication technology (ICT). The relationships between clusters illustrate an integrated research ecosystem ranging from basic theories to practical applications based on technology to improve the quality of modern education as a whole. This visualization provides a comprehensive overview of current research trends in science education and digital literacy as well as the development of critical skills through innovative approaches.

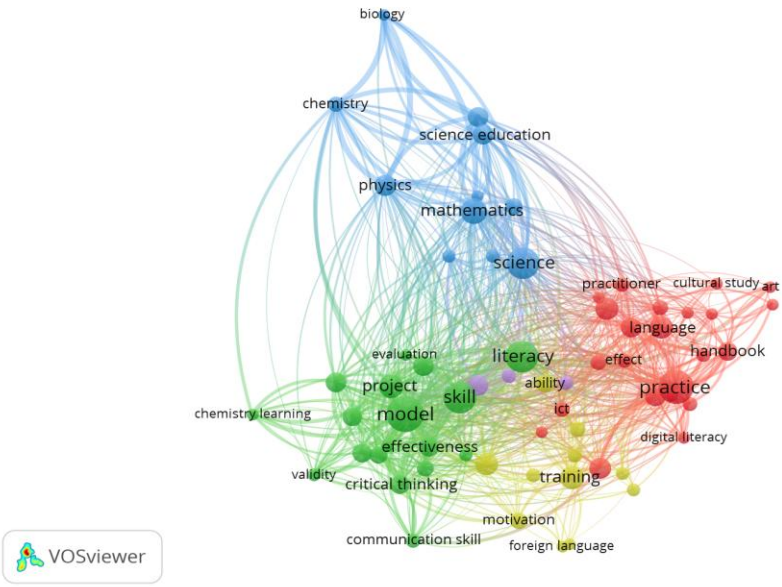

Figure 4. Network Visualization on Trend Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy Research

This keyword network visualization overlay image (Figure 5) shows the development of research trends from 2020 to 2024 based on an analysis of 1000 Google Scholar journals using VOSviewer. The color of the nodes varies from purple to yellow, representing the time of emergence and popularity of terms over that time period, with purple indicating keywords that were more dominant at the beginning of the period (2020) and yellow indicating terms that have become more popular or appeared more in recent years (2023-2024). In general, basic concepts such as biology, chemistry, physics, and science education tend to be greenish yellow, indicating that these topics remain relevant and continue to develop to this day. Meanwhile, terms such as practice, training, and foreign language have a color that is more blue to light green, indicating an increasing research focus in recent years.

In detail, the clusters related to learning models (model, project, critical thinking) and skills (skill, literacy) are dominated by yellowish green, indicating an increasing trend in research attention to the development of innovative learning methods and critical literacy in recent years. The language practice and digital literacy cluster (practice, language, digital literacy) also experienced a significant increase with a combination of bluish green to light yellow, showing that the application of digital technology in language education is a hot topic today. In addition, training, motivation, and foreign language proficiency have emerged as research areas that have begun to receive attention since around 2021-2022 with the potential for further growth. This overlay visualization systematically depicts the dynamics of the evolution of research themes in science education and digital literacy over the past five years while highlighting the shift in focus towards technology integration and critical skills-based learning approaches.

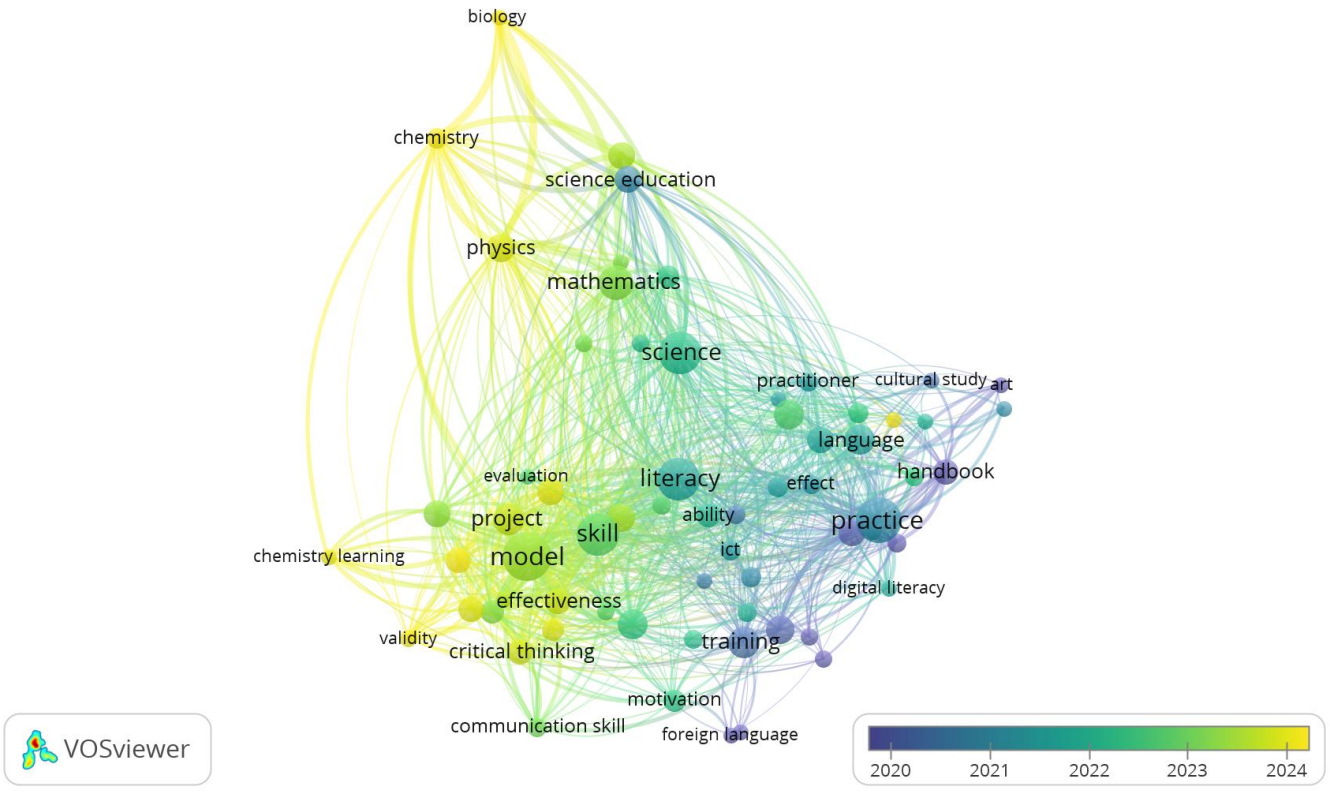

Figure 5. Overlay Visualization on Trend Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy Research

This density shows the concentration of frequency of occurrence and strength of association between key terms in education and literacy research based on an analysis of 1000 Google Scholar journals using VOSviewer. Brighter colors, such as yellow, indicate areas of high density where terms frequently appear together or have strong associations. Keywords such as science, mathematics, literacy, skill, practice, model, and training are seen at the center of the highest densities, indicating that these topics are a major focus

of current research. Terms such as critical thinking and effectiveness also show significant concentration, indicating a strong focus on developing critical thinking skills and evaluating the effectiveness of learning methods.

In addition, the areas with a darker color surrounding the core cluster show supporting concepts such as biology, chemistry, and physics which, although important, have a relatively lower frequency of occurrence compared to the core terms. Words related to language practices (language, handbook) and digital literacy also appear quite prominent but not as high as the learning model and skills cluster. This density visualization systematically illustrates the strong research focus on integrating basic science knowledge with the development of innovative learning models and improving critical skills through practical training, while also providing an overview of how various aspects of education are interconnected in the modern research ecosystem.

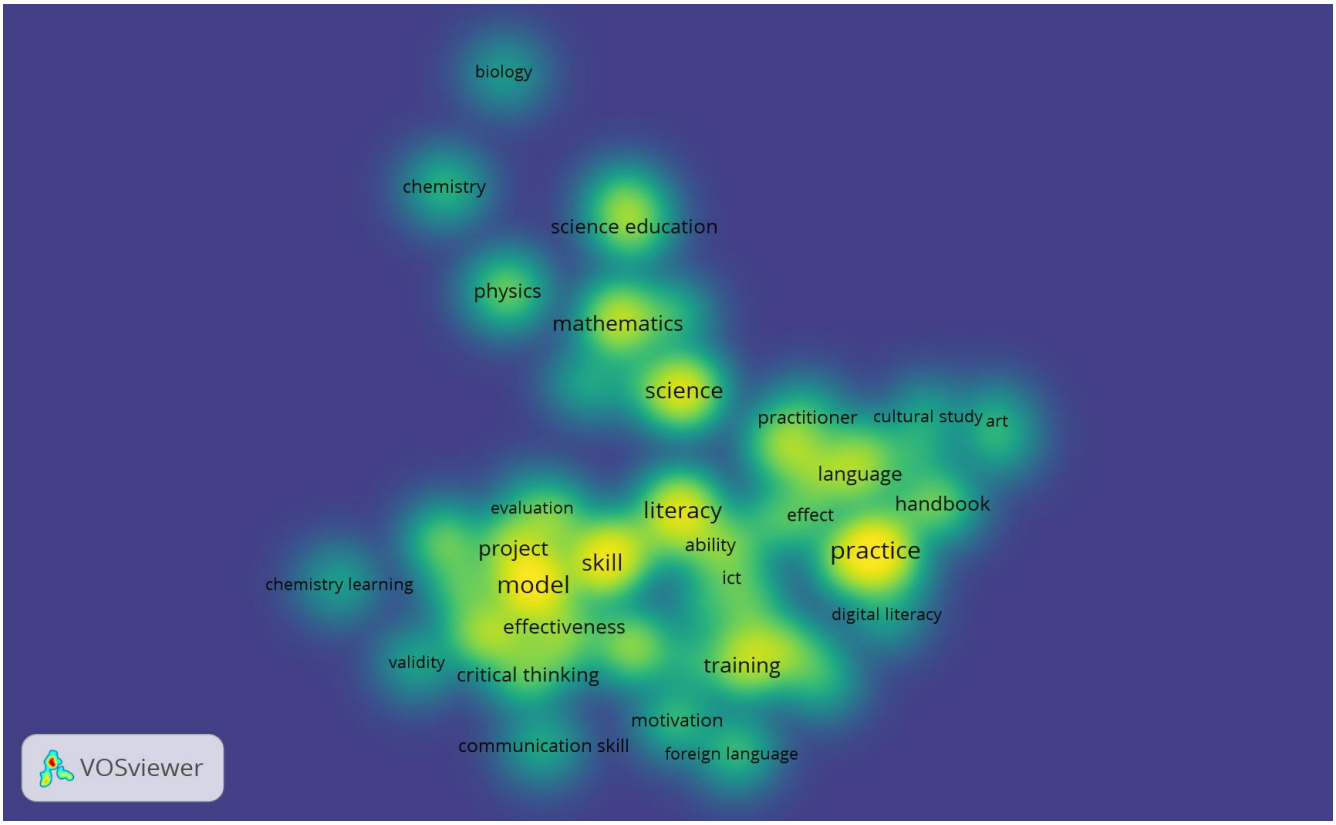

Figure 5. Density Visualization on Trend Problem Based Learning, Ethno-STEM, Augmented Reality, Critical Thinking, and Digital Literacy Research

This study systematically combines Problem-Based Learning (PBL), Ethno-STEM, and Augmented Reality (AR) to improve students' critical thinking skills and digital literacy. This combination is still rarely studied comprehensively in one trend study. The trend analysis method using bibliometrics combined with keyword visualization via VOSviewer provides a clearer and more structured picture of research developments in this field, in contrast to previous studies which were more descriptive or qualitative. This study highlights the latest developments and current trends, especially significant improvements since 2020, thus providing relevant insights for the development of 21st century education in the digital era. This study emphasizes the importance of integrating technology and local cultural context (Ethno-STEM) in learning to support critical thinking skills and digital literacy, which are urgent needs in today's digital era. Highlighting the latest research development trends until 2025, thus providing more up-to-date and relevant insights for the development of education in the digital era.

The results of this review show that the integration of PBL, Ethno-STEM, and AR is not only a trend, but has also been proven effective in improving the quality of learning, especially in developing critical thinking skills and digital literacy. The dominance of publications in the form of book chapters shows that this study is mostly developed in a collaborative and in-depth form, although the publication of scientific articles and proceedings is still relatively low. Network visualization and keyword density also confirm that

the development of innovative learning models is a major focus in the field of modern science education. The significant increase in the number of publications since 2022 shows that this topic is getting more attention and is relevant to be studied further, so it is important to understand the trends and directions of research in order to direct the development of effective learning. Local cultural context (Ethno-STEM) in learning to support critical thinking skills and digital literacy, which are urgent needs in today's digital era. The results of this analysis trend can be a basis for educators, researchers, and policy makers in designing learning models that integrate technology and cultural context to improve the quality of education.

The benefits of this research, for researchers provide a comprehensive research trend map and analysis methodology that can be used as a reference for further research. For educators, it becomes a reference in developing innovative learning models that combine PBL, Ethno-STEM, and AR. For policy makers, it becomes the basis for decision making in developing curriculum and education policies that are relevant to the needs of the 21st century.

Conclusion

Overall, this study shows that the integration of Problem-Based Learning, Ethno-STEM, and Augmented Reality in education has great potential to improve students' critical thinking skills and digital literacy, which are key needs in facing the challenges of the 21st century. Although the publication trend shows fluctuations, interest in this theme continues to increase, especially in the realm of education that emphasizes contextual and technology-based learning. Therefore, the development of innovative learning models that combine these three approaches is worthy of continued development on a wider scale.

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The first author led the conceptualization and developed the methodology and software. The second author contributed to the conceptualization and took primary responsibility for validation alongside the third and fourth authors. The third author conducted the formal analysis, investigation, data curation, and prepared the original draft. The fourth authors provided critical review and editing, supervised the project, and ensured the overall quality and integrity of the research. Visualization was managed by the first author. All authors approved the final version of the manuscript.

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The authors declare that they have no conflicts of interest that could influence the results or interpretation of this study.

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