

[Review Article]

**A SYSTEMATIC LITERATURE REVIEW OF PROBLEM-BASED LEARNING  
INTEGRATED WITH DEEP LEARNING IN DISASTER MITIGATION SCIENCE  
EDUCATION TO ENHANCE SCIENCE LITERACY**

*Azimatul Khusniah<sup>1</sup>, Andin Irsadi<sup>2</sup>, Ani Rusilowati<sup>3</sup>*

*<sup>1,2,3</sup>Department of Magister Science Education, Faculty of Science and Matematic, Universitas  
Negeri Semarang, Semarang, Indonesia  
E-mail: [azimatul\\_khusniah030@students.unnes.ac.id](mailto:azimatul_khusniah030@students.unnes.ac.id)*

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**ABSTRACT**

Indonesia faces high disaster vulnerability, however, disaster mitigation education remains insufficiently integrated into science curricula, contributing to low levels of students' scientific literacy. While Problem-Based Learning (PBL) has been widely implemented to foster higher-order thinking skills, its integration with a cognitive-based Deep Learning approach grounded in meaningful learning, metacognitive engagement, and deep information processing—remains underexplored. This study conducts a Systematic Literature Review (SLR) following PRISMA 2020 guidelines to analyze research trends and gaps in the integration of PBL and Deep Learning within disaster mitigation science education. A total of 11 empirical articles indexed in the Scopus database (2015–2025) met the inclusion criteria and were analyzed using bibliometric mapping (VOSviewer) and qualitative content synthesis. The findings reveal that 10 of 11 studies focus on disaster-related contexts, yet none explicitly integrates PBL syntax with a cognitive Deep Learning framework in a unified instructional design. Research trends are predominantly situated within social science education and Active Learning paradigms, with limited emphasis on structured cognitive deep processing to enhance scientific literacy outcomes. These results indicate a significant methodological and conceptual gap in the literature. The novelty of this review lies in systematically identifying the absence of an integrated PBL–Deep Learning model in disaster mitigation science education and proposing a conceptual foundation for developing a more cognitively grounded and disaster-responsive scientific literacy framework.

Keywords: Deep Learning, Science Literacy, Disaster Mitigation, Problem-Based Learning, Science Learning

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## 1. INTRODUCTION

Indonesia has a high level of vulnerability to various natural disasters, but the integration of disaster education into the school curriculum is often sporadic and lacks depth, resulting in low scientific literacy and student preparedness (Amini et al., 2024; Aroyandini et al., 2025; Desilia et al., 2023). Conventional teacher-centered learning methods are considered ineffective in building a sustainable understanding of mitigation, necessitating a transition to a Problem-Based Learning (PBL) model, which has been proven to improve critical thinking and problem-solving skills in disaster issues (Abdullah & Ningrum, 2024; Sholikhah et al., 2025). However, the procedural application of PBL often does not guarantee the construction of deep meaning or long-term conceptual retention without the support of a pedagogical approach oriented towards high-level cognitive elaboration processes (Dolmans et al., 2016; Taufik et al., 2025).

The integration of a Deep Learning approach that emphasizes meaningful, mindful, and reflective learning into the PBL model is seen as having the potential to strengthen the quality of students' learning experiences (Ain et al., 2025). This approach enables students not only to master science concepts declaratively but also to develop relational understanding, knowledge transfer skills, and metacognitive awareness of their own thinking processes (Zainil et al., 2025). The use of technologies such as Artificial Intelligence (AI) and interactive e-modules is often used as supporting media to enrich the learning experience, but this technology is positioned as a facilitator, not as the primary definition of Deep Learning (Habibah & Fauzi, 2025; Rahman et al., 2023; Santosa, 2025).

Deep Learning is a deep learning approach rooted in constructivism theory and cognitive psychology, particularly through the concept of constructive alignment developed by Biggs and Tang, rather than in Artificial Intelligence- or machine learning-based Deep Learning. This approach is understood as a learning orientation focused on meaning-oriented learning, conceptual integration, critical reflection, and high metacognitive engagement.

Epistemologically, this framework clearly distinguishes between reproductive surface learning and elaborative and transformative deep learning. This clarity of conceptual definition is crucial to avoid terminological ambiguity that often arises in educational literature, which uses the term "Deep Learning" overlapping with artificial intelligence technology.

A number of studies have explored the effectiveness of PBL in science education and the implementation of disaster mitigation education. However, the available literature tends to be fragmented. First, most studies position PBL as a single intervention without explicit integration with a deep learning framework based on cognitive theory (Supahar & Widodo, 2021). Second, studies on Deep Learning in science education generally focus on general academic achievement and have not specifically addressed scientific literacy for disaster mitigation (Waheed et al., 2020). Third, there has been no systematic review that comprehensively maps how the synergy between PBL and Deep Learning approaches contributes to improving scientific literacy in disaster management (Sholahuddin et al., 2021). This situation indicates a conceptual gap, a contextual gap, and a methodological gap that have not been adequately addressed in the scientific literature.

The absence of a comprehensive synthesis has resulted in the development of pedagogical theory and practice remaining fragmented and unintegrated. Therefore, the Systematic Literature Review (SLR) approach is relevant for producing a transparent, systematic, and replicable mapping of scientific evidence. Through the procedures of identification, selection, quality evaluation, and synthesis of research findings, the SLR enables the construction of a more robust, evidence-based conceptual framework.

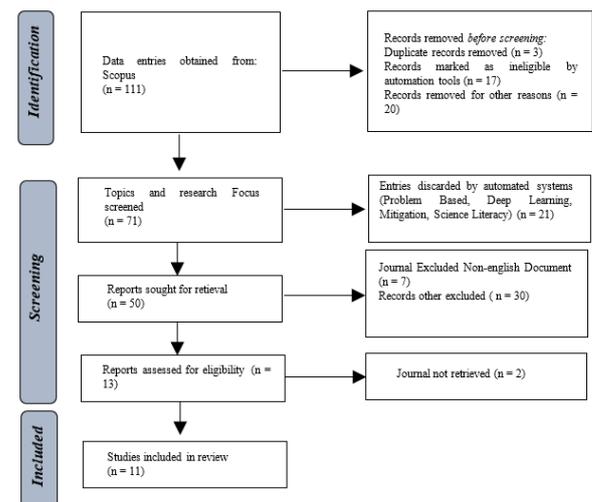
Based on the identified problems and gaps, this study is explicitly designed to analyze the trends and characteristics of research developments on the integration of Problem-Based Learning and Deep Learning approaches in science education related to disaster mitigation, and to evaluate the extent to which the synergy of these two approaches contributes to improving students'

scientific literacy, based on available empirical evidence. Furthermore, this study aims to identify dominant methodological patterns, the strengths of empirical findings, and conceptual weaknesses that still characterize the literature in this field. This synthesis is then used to formulate conceptual implications for the development of science learning models that are more responsive to disaster risks and oriented toward strengthening scientific literacy and student resilience.

The primary objective of this Systematic Literature Review (SLR) is to comprehensively analyze and synthesize the scientific literature on the integration of Problem-Based Learning models with Deep Learning approaches in science education related to disaster mitigation. This research aims to identify patterns of effectiveness, map global research trends, and uncover existing methodological and theoretical gaps in efforts to improve students' scientific literacy. Through a systematic synthesis of empirical and conceptual findings, this study seeks to build a more integrated conceptual framework and provide evidence-based recommendations for the development of a science curriculum that is adaptive, reflective, and oriented towards building student resilience.

## 2. METHOD

This research applies the design of Systematic Literature Review (SLR) to investigate the effectiveness of the model Problem-Based Learning (PBL) approach Deep Learning in science learning that is related to disaster mitigation. The methodological framework is prepared following standard guidelines Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to ensure transparency, reproducibility, and minimization of bias in reporting (Page et al., 2021). The PRISMA protocol is used to guide the article selection flow from identification, screening (Screening), feasibility assessments, to final inclusion, which allows researchers to systematically map the current research landscape (Rethlefsen et al., 2021). Here is a visualization of the article selection flow used.



**Figure 1.** Article Selection Prism Diagram

The literature search strategy was focused on the Scopus database, which was chosen because of its extensive coverage of reputable journals in the fields of science education and disaster management. The search is limited to the most recent publication between 2015 and 2025 to ensure state of the art data. The search was conducted using the Boolean operators technique with a special syntax that combines learning model variables, disaster contexts, and science literacy-bound variables. The search queries used are as follows:

TITLE-ABS-KEY ("Problem-Based Learning" OR "PBL" OR "Deep Learning" OR "Inquiry-Based Learning") AND TITLE-ABS-KEY ("Science Education" OR "STEM" OR "Physics Education" OR "Natural Science") AND TITLE-ABS-KEY ("Disaster Mitigation" OR "Disaster Risk Reduction" OR "Disaster Preparedness") AND TITLE-ABS-KEY ("Scientific Literacy" OR "Science Literacy" OR "Critical Thinking") AND PUBYEAR > 2014 AND PUBYEAR < 2026

The initial search of the Scopus database yielded 111 articles during the identification stage. All articles were then systematically analyzed by searching for keyword suitability, titles, and abstracts to ensure relevance to the research focus, namely the integration of Problem-Based Learning (PBL), a cognitive theory-based Deep Learning approach, and science learning with disaster mitigation content. The screening process was carried out in stages by eliminating articles that did not explicitly discuss the intersection of these three variables or did not

target scientific literacy outcomes. After the selection stage based on conceptual and methodological relevance, 11 articles remained that met the inclusion criteria and were deemed worthy of further analysis in the final synthesis stage. This final number reflects the relatively specific (niche) nature of the topic and indicates that the integration of PBL and Deep Learning in disaster mitigation education is still limited in the Scopus-indexed literature during the 2015–2025 period.

After the search process, the article metadata is extracted in RIS format (Research Information Systems) and managed using Mendeley Reference Manager for the deduplication and citation management process. The selection process is carried out in stages, starting with the screening of titles and abstracts, followed by a review of the full text (full-text) based on strict inclusion and exclusion criteria. Inclusion criteria include empirical journal articles (not book reviews or proceedings) that explicitly address disaster-related science learning interventions, in line with recommendations for maintaining the quality of evidence in systematic reviews of education (Bond et al., 2020).

To increase methodological rigor and minimize selection bias, the screening and eligibility assessment process was conducted by two researchers independently. Inter-rater agreement was calculated using a simple percentage of agreement, and differences in interpretation were resolved through discussion until consensus was reached. This approach was implemented to ensure objectivity in determining which articles were eligible for analysis.

In addition, a quality appraisal of the articles was conducted using adapted criteria from the Mixed Methods Appraisal Tool (MMAT), which included clarity of research objectives, appropriateness of methodological design, instrument validity, transparency of analytical procedures, and consistency of reporting of results. Each article was evaluated using a three-level rating scale (high, medium, and low). Only articles with high and medium methodological quality were retained in the final synthesis, while articles with low quality were excluded from the in-depth thematic analysis. This process was carried out to

maintain the credibility and robustness of the evidence in the SLR conclusions.

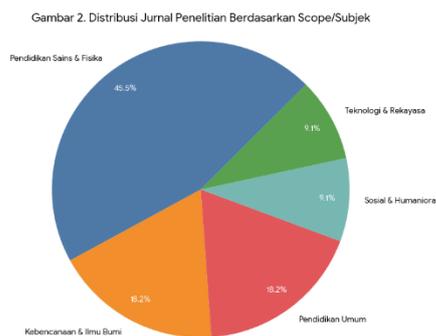
Data analysis was performed using bibliometric parameters assisted by VOSviewer software to guarantee the validity and reliability of the research theme mapping. This approach allows for an objective visualization of the co-occurrence network of keywords and author collaboration, thereby reducing the subjectivity of researchers in determining dominant trends (Donthu et al., 2021). In addition to bibliometric visualization, content analysis was conducted to synthesize how PBL integration and Deep Learning specifically contribute to the improvement of students' science literacy in the context of disaster mitigation, resulting in findings that are valid and methodologically accountable.

### 3. RESULT AND DISCUSSION

Based on the distribution in Figure 2, the predominance of publications in science education (45.5%) indicates that improving student competency through science learning is a primary focus in the identified literature. Disaster journal clusters (18.2%) and other disciplines appear in smaller proportions, indicating that the discourse on disaster mitigation and science pedagogy is developing along relatively parallel paths. Of the 11 articles meeting the inclusion criteria, only 5 (45.5%) explicitly tested classroom learning models, while the remainder were descriptive, media development, or conceptual studies. This proportion indicates that the experimental evidence base related to the integration of pedagogical models remains quantitatively limited. This finding not only indicates thematic fragmentation but also demonstrates that the integration of PBL and Deep Learning has not yet become mainstream in disaster mitigation education research.

The total inclusion of 11 articles indicates that the intersection between PBL, Deep Learning approaches, and disaster mitigation remains a limited area of research in the Scopus-indexed literature. This limitation is not solely due to an aggressive screening process, but rather to a combination of three factors: (1) the use of a single database (Scopus) to maintain indexing

quality; (2) the application of strict inclusion criteria, particularly the requirement that articles be empirical and include scientific literacy variables; and (3) the niche nature of the topic, namely the intersection between PBL, cognitive psychology-based Deep Learning approaches, and disaster mitigation in science education. In other words, the limited number of studies reflects the limitations of research production in this intersection, not simply a technical consequence of the search strategy.

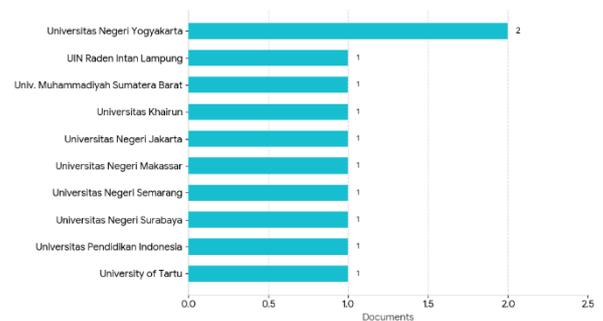


**Figure 2.** Distribution of Research Journals by Scope/Subject

The distribution of author affiliations (Figure 3) shows a dispersed pattern without dominance by any particular research center. Yogyakarta State University contributed two articles (18%), while the other nine institutions each contributed one article (9%). This fragmented distribution, when linked to the quality appraisal results, shows that only four of the 11 studies met the high-quality category, five were of medium quality, and two were of low quality. High-quality studies generally used quasi-experimental designs with standardized instruments, while low-quality studies tended not to report instrument validity or detailed analysis procedures. This condition indicates that apart from the limited number of studies, the methodological depth of research in this field also varies.

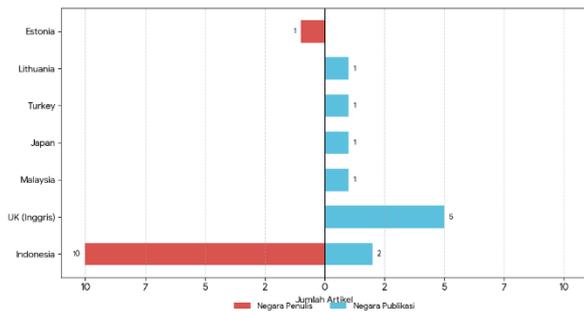
This descriptive data indicates that the research topic has not been dominated by one particular research center, but is still fragmented in various Education Personnel Education Institutions (LPTK). This condition emphasizes the urgency and gap of the research proposed. The absence of a centralized or massive research trend shows

that the integration of the Problem-Based Learning (PBL) model with the Deep Learning approach in the context of disaster mitigation is still rarely carried out systematically. Therefore, the proposed Systematic Literature Review (SLR) research is crucial to synthesize these 'scattered' findings, in order to build a new tested and comprehensive science learning framework.



**Figure 3.** Documents Based on Author Affiliation

Based on the country comparison pyramid diagram, the absolute dominance trend of Indonesian authors (10 documents) can be seen in contrast to the global distribution of publication countries, with the highest concentration in the UK/UK (5 documents). This phenomenon indicates that the issue of disaster mitigation-based science learning is a local urgency that domestic researchers are trying to bring to the international stage. However, the high volume of publications from one country of origin has the potential to give rise to homogeneity of perspective or "repetition" of findings without significant methodological innovation. This is where the gap filled by this research lies: through the Systematic Literature Review (SLR) method, this research is here to critically audit whether the high productivity has been balanced with the novelty of the strategy, especially the integration of Problem-Based Learning with the Deep Learning approach still limited to conventional practices, so that a formula for improving science literacy that is more comprehensive and with global standards can be formulated.



**Figure 4.** Comparison of the Author's Country with the Publication Country

The following is the SLR Review Matrix Table which is systematically compiled based on the 11 articles analyzed. This table is specifically designed to answer the research objectives that map the effectiveness, trends, and find gaps related to the integration of Problem-Based Learning (PBL) and Deep Learning in disaster science literacy.

**Table 1.** Gap Analysis Matrix (Gap Analysis) Visual Based on Research Title Variables

Author (Year)	Model PBL	Deep Learning Approach	Disaster Mitigation Load	Science Literacy	Linkage & Gap Analysis (GAP)
(Saregar et al., 2025)	X	X	✓	✓	Using the <i>Integrated Disaster Education (IDE)</i> model, not PBL. Focus on disaster literacy, not <i>Deep Learning</i> integration.
(Paristiowati et al., 2025)	X	✓	X	X	Key article for <i>Deep Learning</i> variables, but applied to <i>Flipped Classroom</i> and <i>Thermodynamics</i> (not disaster) material.
(Azis et al., 2021a)	✓	X	✓	X	Using PBL in disaster materials, but limited to understanding concepts. There has been no <i>Deep Learning</i> intervention for cognitive deepening.
(Bahri & Tabbu, 2025)	X	X	✓	X	Correlation research. Focus on <i>Computational Thinking</i> and Digital Literacy, not Science Literacy through PBL.
(E. Aroyandini et al., 2025)	X	X	✓	X	Focus on <i>knowledge elaboration</i> in the implementation of education policies, not classroom learning syntax.
(Mulianingsih et al., 2025)	X	X	✓	X	Using <i>Active Learning</i> for HOTS in the context of Social Sciences (IPS), the domain is different from Science Literacy (IPA).
(Saprudin et al., 2024)	X	X	✓	X	Development of interactive media (E-Module) for awareness, not complex pedagogical models of PBL.
(Kenedi et al., 2023)	X	X	✓	X	Virtual-based learning on non-natural disasters (pandemics) is less relevant to natural disaster mitigation based on physical science.
(Agusty et al., 2021)	X	X	✓	X	Literature review on STEM approaches in media. STEM has a different construction from <i>Deep Learning cognitive psychology</i> .
(Oyao et al., 2015)	X	X	✓	✓	Theoretical articles ( <i>framework</i> ) on science competence and DRR. Conceptually relevant, however, the data is old and does not test specific models.
(Septikasari et al., 2024)	X	X	✓	X	Preliminary studies ( <i>needs assessment</i> ) on material integration strategies have not yet reached the learning model trial.
Upcoming research	✓	✓	✓	✓	<b>Filling the Gap:</b> Integrating PBL and <i>Deep Learning</i> in the context of Disaster Mitigation to improve Science Literacy.

### Symbol Description:

✓ (Tick): The variable appears/is explicitly applied and is the main focus of the article.

✗ (Cross): The variable does not appear, or appears but is not the main focus (e.g., only general material, different models, or different bound variables).

Table 1 shows the fragmentation of learning models among 11 articles, where there has not been a single study that unifies syntax Problem-Based Learning (PBL) with the Deep Learning in its entirety. Azis et al., (2021) does apply PBL, but does not integrate it with cognitive deepening strategies. Instead, Paristiowati et al., (2025) successfully proved the effectiveness of the approach Deep Learning, but implement it through the Flipped Classroom, not PBL. Meanwhile, nine other researchers used a completely different approach: (Saregar et al., 2025) with Integrated Disaster Education, Mulianingsih et al. with Active Learning, Saprudin et al., (2024) and Agusty et al., (2021) Agusty et al. who focus on media/STEM development, as well as Kenedi et al. with virtual learning. Other studies such as E. N. Aroyandini et al., (2025) Bahri & Tabbu (2025), Oyao et al., (2015), Septikasari et al., (2024) are more relational, policy descriptive, or theoretical frameworks without the intervention of specific pedagogical models in the classroom. Absence of a wedge between PBL (Azis) and Deep Learning (Paristiowati) in other studies (Agusty et al., 2021; E. N. Aroyandini et al., 2025; Bahri & Tabbu, 2025; Kenedi et al., 2023; Mulianingsih et al., 2025; Oyao et al., 2015; Saprudin et al., 2024; Saregar et al., 2025; Septikasari et al., 2024) emphasizing the opportunity for methodological novelty carried out by this research.

In terms of material content, the table visualizes the dominance of the disaster mitigation context which is very strong but has not been worked on with modern cognitive psychology approaches (Deep Learning). It was recorded that 10 out of 11 articles specifically discussed disasters, namely a study by (Agusty et al., 2021b; E. Aroyandini et al., 2025; Azis et al., 2021b; Bahri & Tabbu, 2025; Kenedi et al., 2023; Mulianingsih et al., 2025; Oyao et al., 2015; Saprudin et al., 2024; Saregar et al., 2025; Septikasari et al., 2024). However, the only

process information in depth was actually carried out by Paristiowati et al. in general thermodynamics material that was not loaded with disaster mitigation. This creates a significant contextual gap: strategy Deep Learning that has proven to be effective (Paristiowati) has never been tested to solve the complexity of disaster mitigation materials that have been researched by the majority of authors (Agusty et al., 2021; E. Aroyandini et al., 2025; Azis et al., 2021b; Bahri & Tabbu, 2025; Kenedi et al., 2023; Mulianingsih et al., 2025; Oyao et al., 2015; Saprudin et al., 2024; Saregar et al., 2025; Septikasari et al., 2024), so this research is here to bridge these strategies into the context of disasters.

In the aspect of bound variables, the table shows that there is no consensus on the output in the form of "Science Literacy" produced through PBL-Deep Learning interventions. Saregar et al. focus on Disaster Literacy, while Paristiowati et al. target Digital Literacy. Other studies targeted different cognitive aspects: Computational Thinking on Bahri & Tabbu, HOTS on Mulianingsih et al., (2025), as well as conceptual understanding or awareness (Awareness) on Agusty et al. (2021), Aroyandini et al. (2025), Azis et al. (2021), Bahri & Tabbu (2025) Kenedi et al. (2023) Mulianingsih et al. (2025), Oyao et al. (2015), Saprudin et al. (2024) Septikasari et al. (2024) more out-oriented in the form of media, policy implementation, or general competencies Risk Reduction. Thus, this research fills the gap in these outputs by targeting "Science Literacy" specifically, which is different from the focus of disaster literacy (Saregar) or digital literacy (Paristiowati et al., 2025), and go beyond just understanding the basic concepts that were the focus of previous research (Agusty et al., 2021; Aroyandini et al., 2025; Azis et al., 2021; Bahri & Tabbu, 2025; Kenedi et al., 2023; Mulianingsih et al., 2025; Oyao et al., 2015; Saprudin et al., 2024; Septikasari et al., 2024).

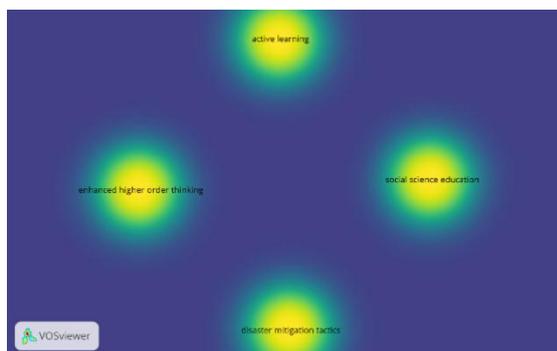
The visualization of the VOSviewer network in Figure 5 presents strong empirical evidence regarding the current research gap, where the disaster mitigation discourse is still dominated by the Social Science Education domain with the general pedagogical umbrella of Active Learning which leads to Higher Order Thinking. This map implicitly confirms a crucial "empty space": the

unidentified research clusters that integrate specific models of Problem-Based Learning (PBL) and Deep Learning approaches in the context of Science Learning to produce Science Literacy. Therefore, this research is strategically positioned to bridge this fragmentation by offering a more specific and measurable instructional framework beyond the current dominant social science paradigm.



**Figure 5.** Network Visualization

The visualization of the density of VOSviewer in Figure 6 presents strong empirical evidence regarding the current research gap, where the map shows high saturation (bright yellow zone) in the domain of Social Science Education and the general pedagogy of Active Learning. In contrast, areas that represent specific integration between Problem-Based Learning (PBL) and Deep Learning approaches in the context of Natural Science look empty or are in the dark blue zone that indicates a lack of exploration. This visual phenomenon emphatically validates the position of novelty of this research, which is present to fill the empty space by shifting the focus from social paradigms and general thinking skills towards the construction of specific science literacy through deep and tested learning syntax.



**Figure 6.** Density Visualizatio

#### 4. CONCLUSION

This Systematic Literature Review (SLR) analyzed 11 articles that met the inclusion criteria from the Scopus database and concluded that the research landscape related to the integration of disaster mitigation learning into science education remains significantly fragmented. Studies predominantly focus on general pedagogical approaches such as Active Learning with Higher Order Thinking Skills (HOTS) outcomes, while the specific integration of Problem-Based Learning (PBL) and Deep Learning approaches within a scientific literacy framework has not been systematically developed. Of the 11 articles analyzed, 10 addressed the issue of disaster mitigation, but only one explicitly used PBL, and one examined the Deep Learning approach separately. No studies simultaneously integrated both approaches within a science learning context to improve scientific literacy. These findings indicate significant methodological and conceptual gaps at the intersection of these three variables.

The primary contribution of this review lies in mapping this evidence-based research gap and formulating an integrative conceptual framework that synergizes the problem-solving structure in PBL with the principles of deep cognitive processing in Deep Learning. Unlike previous studies that tended to focus on general disaster literacy or critical thinking skills, this study specifically emphasizes science literacy as a measurable, discipline-based outcome. Theoretically, these findings broaden the discourse on the integration of pedagogical strategies and cognitive approaches in disaster science education. Practically, the results of this synthesis can serve as a foundation for developing learning designs, curricula, and further experimental research testing the effectiveness of this integrative model.

However, this study has several limitations. First, the data source was limited to a single international database (Scopus), so there may be relevant articles in other databases that were not identified. Second, the number of studies meeting the inclusion criteria was relatively small ( $n = 11$ ), reflecting the limited research output on this topic and limiting the generalizability of the

findings. Third, the geographic dominance of Indonesian authors potentially influences the diversity of theoretical perspectives and implementation contexts. Therefore, future research is recommended to expand the database's scope, incorporate a quantitative meta-analysis approach if the number of studies is sufficient, and empirically test the proposed integrative model in various educational contexts and geographic regions.

Thus, this study not only identifies the fragmentation of literature, but also provides a direction for the development of more structured and data-driven research in integrating PBL and Deep Learning to strengthen scientific literacy in disaster mitigation learning.

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