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Journal of Mathematics Instruction, Social Research and Opinion
Vol. 5, No. 2, June 2026, pp. 1685 – 1693, https://doi.org/10.58421/misro.v5i2.1406
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Early Mapping of Student Science Literacy: A Preliminary Study for Tidal Flood Mitigation Learning Innovation Based on Deep Learning and Local Wisdom

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Article Info

Article history:

Received 2026-04-13
Revised 2026-05-28
Accepted 2026-06-10

Keywords:

Deep Learning
Disaster Education
Local Wisdom
Science Literacy
Tidal Flood Mitigation

ABSTRACT

This study aims to provide an initial quantitative mapping of coastal students' science literacy related to tidal flood mitigation, addressing the limited contextual understanding of disaster adaptation in schools. Using a quantitative descriptive survey design, the study involved 360 students from three coastal vocational high schools selected through proportional stratified random sampling. Data were collected through a PISA-based science literacy test and disaster mitigation perception questionnaires, then analyzed using descriptive statistics, One-Way ANOVA, and Pearson correlation tests. The findings showed that students' overall science literacy was at a moderate level (mean = 68.61). Students demonstrated relatively good data interpretation skills (mean = 76.83), while their ability to explain natural phenomena scientifically remained lower (mean = 62.15). The ANOVA test indicated no significant difference in science literacy among the three schools ($p = 0.946$). In addition, a very strong positive correlation ($r = 0.82$) was observed between science literacy and students' perceptions of disaster resilience. The novelty of this study lies in its integration of coastal disaster literacy mapping with a deep-learning pedagogical approach grounded in local wisdom. These findings provide empirical evidence that science literacy in coastal schools remains insufficiently connected to students' environmental realities, highlighting the importance of contextual and culturally responsive science learning for disaster mitigation education.

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1. INTRODUCTION

Global climate change has increased the frequency and intensity of hydrometeorological disasters, including tidal floods that threaten coastal communities [1], [2]. In Indonesia, the intensification of tidal floods not only triggers damage to physical infrastructure but also collapses the socio-economic order of the community and disrupts the continuity of education, especially in areas with a high rate of land subsidence [3], [4]. Facing the complexity of this environmental disaster, integrated mitigation education in schools is an essential instrument to build preparedness and adaptation capacity for the younger generation [5], [6]. Unfortunately, the implementation of disaster education in the field is often still technocratic and lacks contextuality, thus failing to equip students with adequate science literacy to understand and respond to environmental threats critically and responsively [7], [8].

Science literacy plays an important role in helping students understand scientific phenomena, evaluate evidence, and make informed decisions related to environmental problems and disaster risks. In coastal areas vulnerable to tidal floods, science literacy is not only related to academic achievement but also to students' adaptive capacity in responding to environmental changes. Therefore, strengthening science literacy through contextual and locally relevant learning is considered essential for improving disaster preparedness among young generations in coastal communities.

Empirical data in the field show that students' science literacy and disaster adaptability levels are currently still in the alarming category. The results of quantitative measurements in the preliminary study noted that the average score of disaster adaptability in school students only reached 54.39 out of a scale of 100, which indicates low mitigation sensitivity [9]. More specifically, the achievement of science literacy indicators in the context of disasters is very weak; students' competence in interpreting scientific data is only 49.8%, while the ability to make decisions based on scientific evidence is the lowest at 36.9% [10].

This is in line with findings from observations in various schools, which show that students' understanding of science is still centered on theoretical memorization, with achievement in aspects of the science context at only 40% (very lacking category) [11], [12]. The lack of interactive educational instruments makes students fail to connect academic knowledge with the reality of the tidal flood phenomenon that occurs in their surroundings [13].

From social, cultural, and educational perspectives, strengthening science literacy through contextual learning is highly important for coastal communities. One relevant approach is ethnoscience-based learning that integrates local wisdom into science education. Through this approach, students can understand disaster mitigation concepts by drawing on cultural practices and local knowledge that have historically been applied by coastal communities, such as traditional architectural systems and natural sign recognition as early warning strategies [14], [15], [16].

In addition to local wisdom, technology also offers opportunities to support disaster mitigation learning. In this study, the term "Deep Learning" refers to artificial intelligence-based computational modeling, particularly machine learning techniques used to simulate and predict tidal flood patterns [17]. AI-based modeling has the potential to support the visualization and prediction of tidal flood phenomena in educational contexts. Previous studies reported that integrating local wisdom with digital and AI-supported learning can help students better understand abstract environmental phenomena through contextual and interactive learning experiences [18], [19].

Although the integration of local wisdom and AI-based technology shows promising potential, there is still a significant literature gap in previous research. Most studies on mitigation education are still conducted separately; Some research only focuses on the development of print ethnoscience modules without the presence of applied technology impediments [11], while research that develops algorithms Deep Learning (such as LSTM or Random Forest) for the prediction of inundation is dominated by pure hydrological engineering without being transformed into a form of pedagogical design in the classroom [2], [20]. In addition, it is very rare to find studies that conduct initial mapping (Baseline Mapping) using a quantitative methodology to measure students' cognitive profiles and science literacy before applying advanced integration models [21], [22]. Absence of data baseline. This quantitative gap leads to technological innovations and disaster modules that are often developed without considering the sociocultural profile and cognitive readiness of the intended students.

Unlike previous disaster literacy studies, this research provides an initial quantitative mapping of coastal students' science literacy related to tidal flood mitigation before the implementation of contextual learning innovation. This study aims to quantitatively identify students' science literacy profiles in coastal vocational schools, particularly in interpreting scientific data and understanding disaster-related phenomena. The findings of this study are expected to provide an empirical basis for developing contextual and culturally responsive disaster mitigation learning that integrates local wisdom and AI-based modeling to support coastal resilience.

2. METHOD

This study uses a quantitative research design with a descriptive-survey approach. This approach was chosen to conduct empirical mapping of students' science literacy profiles as part of the Preliminary Study within the framework of developmental research [23]. The main focus of this study is to measure students' science literacy indicators in the field before constructing mitigation learning innovations that combine excellence in Deep Learning and the context of local wisdom. Theoretically, this approach aims to bridge the concept of Ethno-STEM with modern technology to increase the resilience of coastal communities [24].

In this study, science literacy refers to students' ability to explain scientific phenomena, interpret scientific data, and make evidence-based decisions related to tidal flood mitigation, as defined by the PISA science literacy framework. Meanwhile, disaster resilience perception refers to students' awareness, preparedness, and adaptive understanding of tidal flood risks in coastal environments.

The primary data were collected using a science literacy test and a disaster mitigation perception questionnaire. The science literacy instrument was developed based on the PISA framework and included competencies in explaining scientific phenomena, evaluating scientific inquiry, and interpreting scientific data [25]. The questionnaire and literacy test were developed through several stages, including indicator identification, item construction, expert validation, pilot testing, and instrument revision. The scoring system ranged from 0 to 100, with higher scores indicating better literacy competencies.

Prior to data collection, the instrument was validated by three experts in science education and disaster mitigation to assess content relevance and construct appropriateness. Reliability testing using Cronbach's Alpha produced a coefficient of 0.87, indicating high internal consistency of the instrument.

The sampling technique used is Proportional Stratified Random Sampling. Given that the population of this study comprised three schools with varying student numbers (Total N = 3,649), this technique ensures that each school is proportionally represented in the sample [23]. The determination of the minimum sample size was calculated using the Slovin formula with an error rate (α) of 5%, so that a sample of 360 students was obtained. After the quota per school is determined, the selection of subjects in each school is carried out randomly to minimize research bias.

Table 1. Distribution of Research Samples (Margin of Error 5%)

School Name	Total Population (N)	Proportion (%)	Number of Samples (n)
SMK Islam Al-Khoiriyah Petarukan	884	24,2%	87
SMKN 1 Ampelgading	2.136	58,5%	211
SMKN 1 Petarukan	629	17,3%	62
Total Schools	3.649	100%	360

Data analysis was conducted using JASP software [26]. Descriptive statistics were used to calculate means, percentages, and frequency distributions of science literacy indicators. Prior to inferential testing, normality and homogeneity tests were conducted to ensure the data met the assumptions for One-Way ANOVA. Pearson's correlation analysis was subsequently applied to examine the relationship between science literacy and perceptions of disaster resilience.

Ethical considerations were applied throughout the study. Research permission was obtained from the participating schools, and all participants were informed of the research objectives. Participation was voluntary, and students' identities and responses were kept confidential for research purposes only.

3. RESULTS AND DISCUSSION

3.1. Result

To address the research objectives related to mapping the initial profile of coastal students' science literacy for tidal flood mitigation, data from 360 respondents have been extracted and analyzed quantitatively. The results of descriptive statistical measurements, including mean values, standard deviations, and minimum and maximum score ranges, for the three PISA indicators and mitigation perceptions are presented in Table 2. Furthermore, in order to test the significance of the difference in science literacy levels between the sample populations and to determine whether future pedagogical interventions require different treatment based on the origin of the institution (SMK Islam Al-Khoiriyah, SMKN 1 Ampelgading, and SMKN 1 Petarukan), parametric inferential testing was carried out using the One-Way ANOVA method. A summary of the results of the comparative hypothesis test is presented in Table 3. The presentation of these two empirical data in sequence provides a fundamental analytical foothold before further interpretation of the urgency of developing adaptive learning systems based on Deep Learning and local wisdom.

Table 2. Statistical Description of Science Literacy Score and Mitigation Perception.

Variable	N	Red	Std. Deviation
Indicator 1 (Explaining the Phenomenon)	360	62.15	10.42
Indicator 2 (Evaluating the Investigation)	360	66.83	11.05
Indicator 3 (Interpreting Data)	360	76.83	11.05
Total Science Literacy Score	360	68.61	10.56
Perception of Mitigation	360	41.50	5.21

Table 3. ANOVA One-Way Test (Comparison of Literacy Scores Based on School Origin)

Case	Sum of Squares	df	Mean Square	F	p
Inter-School	12.450	2	6.225	0.055	0.946
Residual	40,025.100	357	112.115		

Note: A p-value of > 0.05 indicates no statistically significant mean difference between the three schools.

Quantitative mapping analysis executed through JASP software showed that students' science literacy profiles regarding tidal flood mitigation in all three coastal vocational high schools were at moderate equilibrium, with a cumulative average of 68.61 (SD = 10.56). An analysis of anomalies in the PISA sub-indicator revealed a crucial cognitive gap: the sample group demonstrated sufficient proficiency in interpreting data and evidence scientifically (average 76.83), but experienced a fundamental deficit in explaining disaster phenomena with scientific precision (average 62.15). This finding indicates differences in students' literacy competencies, with students being relatively stronger at reading and interpreting information than at explaining disaster phenomena scientifically.

The One-Way ANOVA test showed no significant difference in science literacy scores among students from the three coastal vocational schools ($F = 0.055$; $p = 0.946$). This suggests that students from the three schools had relatively similar literacy profiles despite differences in school background. In addition, Pearson correlation analysis revealed a very strong positive relationship between science literacy and disaster mitigation perception ($r = 0.82$; $p < 0.001$). In practice, this result indicates that students with higher science literacy tended to demonstrate greater awareness and understanding of disaster mitigation.

3.2. Discussion

The findings indicate that coastal students' science literacy related to tidal flood mitigation remains moderate. Although students showed relatively good ability in interpreting scientific data, their competence in explaining scientific phenomena was comparatively lower. This pattern is consistent with the PISA science literacy framework, which emphasizes that students often struggle in applying scientific concepts to real-world environmental problems [25].

Lower achievement in explaining scientific phenomena may indicate that science learning in coastal schools remains more focused on theoretical understanding than on contextual problem-solving. Several previous studies also reported that disaster-related science learning frequently lacks connection with students' surrounding environmental experiences [27], [28]. As a result, students may recognize disaster events empirically but still encounter challenges in scientifically explaining the causes, impacts, and mitigation processes of tidal floods.

Another important finding is the absence of significant differences in science literacy scores among the three schools. This result suggests that students from different coastal schools may experience relatively similar environmental exposure and educational conditions regarding tidal flooding. The similarity of literacy profiles also indicates that disaster-related science learning challenges are not limited to a single school but may reflect broader conditions in coastal education contexts. Because the three schools are located in northern coastal areas that experience recurring tidal floods, students tend to share similar environmental experiences and disaster exposure patterns. However, these experiences have not been fully transformed into structured scientific understanding within classroom learning activities.

These findings support previous studies by Suryaningrum et al. and Hasyim et al., which reported that students in disaster-prone areas often develop practical awareness based on direct environmental experiences but still face difficulties in scientifically interpreting disaster phenomena due to limited contextual integration in science learning [27], [28]. The relatively low score in explaining scientific phenomena (62.15) may therefore reflect the limited use of contextual and locally relevant learning approaches in disaster education.

The strong positive correlation between science literacy and perceptions of mitigation demonstrates that scientific understanding is closely associated with students' disaster awareness and preparedness. This finding supports previous studies that emphasize that science literacy plays an important role in developing informed attitudes and adaptive responses to environmental risks [29], [30], [31]. In practice, this result indicates that improving students' understanding of scientific concepts may also strengthen their awareness and preparedness for tidal flood disasters.

This study also highlights the importance of contextual science learning that integrates local environmental issues and local wisdom into classroom activities. In coastal communities, local knowledge related to environmental signs, traditional adaptation strategies, and community experiences may provide relevant contextual resources for science learning. Integrating such contextual elements into science education may help students better connect scientific concepts with real environmental challenges.

The findings of this study also respond to gaps identified in previous disaster science education studies. Earlier research on ethnoscience and disaster education has predominantly focused on printed teaching materials or general contextual learning media [29]. However, limited studies have quantitatively mapped students' science literacy profiles as a preliminary basis for developing more adaptive disaster mitigation learning. Therefore, this study provides empirical baseline data on coastal students' literacy conditions before the implementation of additional learning innovations.

Although this study did not implement a specific intervention model, the results provide an important foundation for future research related to contextual disaster mitigation learning. In this study, the term "Deep Learning" refers to artificial intelligence-based computational modeling that may potentially support interactive learning visualization in future educational development. However, the current research was limited to baseline mapping of students' science literacy and perceptions of mitigation. Therefore, future studies may further examine the effectiveness of contextual learning approaches, including Problem-Based Learning integrated with local wisdom and technology-supported learning, in improving students' science literacy and scientific attitudes in coastal education settings.

4. CONCLUSION

The results of this study indicate that coastal students' science literacy related to tidal flood mitigation was generally moderate, with an average score of 68.61. Students demonstrated stronger competence in interpreting scientific data and evidence than in explaining disaster-related scientific phenomena. In addition, the One-Way ANOVA test showed no significant differences in science literacy among the three coastal vocational schools, indicating relatively similar literacy profiles across schools. The strong positive correlation between science literacy and mitigation perception also suggests that students with higher scientific understanding tend to demonstrate better disaster awareness and preparedness.

These findings highlight the importance of developing contextual science learning that connects scientific concepts with students' environmental experiences and local coastal conditions. The study contributes important baseline data regarding coastal students' science literacy profiles, which may serve as an empirical reference for the development of disaster mitigation learning in coastal education settings.

This study was limited to a descriptive-survey design and did not evaluate the effectiveness of specific learning interventions. Therefore, future studies are recommended to examine the implementation of contextual learning approaches, including the integration of local wisdom and technology-supported learning, to improve students' science literacy and disaster preparedness.

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