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FIFTH GRADE STUDENTS' SCIENCE LITERACY PROFILE AS A BASIS FOR DEVELOPING EDUCATIONAL GAMES

Dewi Astuti*[1a], Wuri Wuryandani[2b], and Supartinah [3c]

[1,2,3]Elementary Education, Faculty of Education and Psychology Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

[a]*E-mail: dewiastuti.2025@student.uny.ac.id*
[b]*E-mail: wuri_wuryandani@uny.ac.id*
[c]*E-mail: supartinah@uny.ac.id*

(*)Corresponding Author
dewiastuti.2025@student.uny.ac.id

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ABSTRACT
Scientific literacy needs to be cultivated from elementary school so that students are able to solve problems based on scientific evidence. However, previous research has not mapped the profile of inter-aspects and interlocking causal factors at the elementary school level. This study aims to describe the profile of scientific literacy, identify the factors causing low achievement, and develop recommendations. Through a qualitative case study at Kalibawang Public Elementary School, data were collected from 30 fifth-grade students and one teacher selected purposively using questionnaires, observations, and interviews, then analyzed interactively. The results show a scientific literacy profile in the sufficient category (average 3.16) with a striking gap: scientific responsibility competency was the highest (3.29), while science career information (2.85) and environmental responsibility (2.86) were the lowest. Low scientific literacy is caused by three interlocking factors: teachers' limitations in developing textbook-based assessments, a lack of interactive media, and the scarcity of project-based learning due to the dominance of the transmissive pattern. The novelty of this research lies in revealing the relationship between these three factors and proposing a mission-based educational game as a contextual solution. The implication is that training is needed in developing digital instruments and media, allocating time for integrated STEM projects, school policies that support innovative models, and developing mission games to improve scientific literacy sustainably.

INTRODUCTION

Education is the most effective tool for improving the quality of a nation's future generations and ensuring sustainable development. Quality education equips individuals with the ability to interpret things accurately and apply information to real-life situations (Thangeda & Baratiseng, 2016). One of the essential pillars of quality education is the study of Natural and Social Sciences (IPAS). Through IPAS, students not only gain an understanding of natural phenomena but also develop critical thinking skills and a knowledge base for further education in science and technology (Anggraeni & Suratno, 2021; Forawi, 2016).

Scientific literacy is a fundamental skill that must be cultivated from elementary school. Scientific literacy is an individual's ability to understand scientific concepts, communicate scientific information, and utilize that knowledge to solve problems (Li & Guo, 2021; Uus et al., 2017). The Programme for International Student Assessment OECD (2015), defines scientific literacy as the ability to critically relate scientific knowledge to various issues in social life. OECD (2019),emphasizes that scientific literacy includes the ability to explain phenomena scientifically, evaluate and design investigations, and critically interpret data and evidence. Scientific literacy, within the PISA assessment framework, consists of four main elements: context, knowledge (content, procedural, and epistemic), competencies, and attitudes (OECD, 2019). This study focuses on three main aspects: context, competencies, and attitudes, which are key indicators for mapping the scientific literacy profile of elementary school students.

The reality on the ground shows a concerning condition. Based on interviews and observations with fifth-grade teachers at Kalibawang Public Elementary School, Kulonprogo, in April 2026, students' scientific literacy remained low. Their scientific literacy competency was limited to basic knowledge; teachers had to direct students to read encyclopedias and research environmental issues to broaden their knowledge. The results of the student needs questionnaire revealed low data on aspects of students' views on science lessons (only 60%), obstacles in scientific literacy (58.33%), use of innovative media (62.5%), methods (58.25%), and development of scientific literacy instruments (69.5%). This low achievement was caused by minimal training in scientific literacy learning innovations for teachers, limited infrastructure, learning time, and the lack of availability of scientific literacy competency and attitude instruments that teachers must develop independently. As a result, teachers lack innovation in integrating instruments, media, models, and methods that can improve students' scientific literacy. This condition makes students less active in constructing their own knowledge and makes it difficult for them to understand the material, solve problems, draw conclusions, and apply scientific concepts in everyday life.

These local findings align with global and national data. Survey results OECD (2019), indicate that Indonesia's scientific literacy achievements are low across all aspects. In the 2018 PISA (Pacific Economic Assessment) survey, Indonesia ranked 62nd out of 71 countries for scientific competency. Nationally, only 25.38% of students were deemed adequate in their scientific literacy, while 73.61% were deemed inadequate. Yustin and Wiyarsi, (2019), emphasized that the learning environment and school climate influence variations in student literacy scores, and (Jufri et al., 2016) revealed that science learning still focuses on memorization, not understanding. This condition is a serious alarm regarding the low scientific literacy abilities of students in Indonesia, including at Kalibawang Public Elementary School.

The risks arising from low scientific literacy cannot be underestimated. Without adequate scientific literacy, students will struggle to connect scientific knowledge to real-world phenomena, explain events scientifically, design simple experiments, interpret data, and make evidence-based decisions. This will result in a generation that is ill-prepared to face developments in science and technology, weak in problem-solving, and left behind in global competition. Low scientific literacy also has the potential to diminish students' interest in science and technology, ultimately impacting the availability of superior human resources in the future (Fortus et al., 2022). Therefore, learning interventions are needed that not only measure but also stimulate mastery of the three aspects of scientific literacy in an integrated manner.

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Various efforts have been made to improve scientific literacy, including through the STEM approach, the use of educational games, and project-based learning. However, previous research has tended to focus on the effectiveness of specific learning models without first in-depth mapping of students' scientific literacy profiles across three dimensions (context, competency, and attitude) at the elementary school level. One relevant solution is the development of educational games. Educational games are games specifically designed for teaching purposes, running on computers, laptops, or handheld devices (Kokotsaki et al., 2016). The use of educational games can replace traditional exercises, motivate students, provide immediate feedback, and improve knowledge retention and attention (Prensky, 2021; Topîrceanu, 2017).. The current generation of learners is highly familiar with video games and spends a significant amount of time playing them (Cheng et al., 2015), so the potential of games for educational applications deserves serious consideration. Educational games in the context of scientific literacy can foster depth of understanding through challenging missions, while simultaneously measuring students' achievement in aspects of context, competence, and scientific attitudes.

However, current educational game innovation is still suboptimal. Many educational game developments remain confined to the academic realm and have not yet been translated into applications that are widely accessible to students (Almeida & Simoes, 2019). Furthermore, existing educational games often overemphasize entertainment, while their educational content lacks depth or is not effectively integrated with learning objectives (Damarjati & Miatun, 2021; Supriyaddin et al., 2023). This imbalance has led to the underutilization of educational games' potential as a fun and meaningful learning medium for improving scientific literacy.

This imbalance has led to the underutilization of educational games' potential as a fun and meaningful learning medium to improve the quality of learning, particularly in mastering important concepts such as scientific literacy. In response to this gap, this study uses a mission-based educational game application specifically designed to measure and improve three dimensions of scientific literacy (context, competency, and attitude) in elementary school students. The application is available on an easily accessible digital platform, is suited to the characteristics of digital native students, and offers a balance between entertainment and in-depth learning materials.

The novelty of this research lies in the simultaneous disclosure of a three-dimensional scientific literacy profile, identification of interlocking causal factors, and the proposed concrete solution in the form of developing a mission-based educational game tailored to the weaknesses identified in the field. The mission-based game is designed to balance entertainment and depth of content, thus integrating students' scientific context, competency, and attitudes into the learning process (Prensky, 2021; Topîrceanu, 2017).

Based on this urgency, this study aims to describe the profile of students' scientific literacy at Kalibawang Public Elementary School in the aspects of knowledge (content and procedural), competency, and attitude; identify specific difficulties faced; and formulate recommendations for handling as a basis for developing targeted educational games. The formulation of the problem raised is "How is the description of students' scientific literacy abilities in the aspects of context, competency, and attitude?" The results of this study are expected to be a strong empirical foundation for the development of interactive learning media that can improve the quality of elementary school students' scientific literacy in a sustainable manner.

METHOD

Type and design

This research employed a qualitative approach with a case study design. This choice allowed for an in-depth examination of students' scientific literacy profiles and the science learning process at Kalibawang Public Elementary School in a natural setting (Creswell, J. W., & Poth, 2018). The single-case study design was chosen because the research focused on a single location to answer the question "how" students' scientific literacy abilities are portrayed across context, competency, and attitude.

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This research used a qualitative approach with a single case study design at Kalibawang Public Elementary School, Kulonprogo Regency. Subjects were selected using purposive sampling, consisting of 30 fifth-grade students and one fifth-grade teacher with direct experience in teaching scientific literacy. The principal was involved as a supporting informant to provide an overview of the school's policies regarding science learning.

Primary data were collected through observations of the learning process, semi-structured interviews with teachers and student representatives, and a scientific literacy questionnaire completed by all students. Observations focused on the emergence of scientific literacy indicators, namely the ability to explain phenomena scientifically, evaluate and design investigations, and interpret data and evidence. Interviews explored the planning, implementation, and obstacles of science learning. The questionnaire was structured using a four-point Likert scale (1 = strongly disagree to 4 = strongly agree) to measure three main aspects: students' attitudes, context, and science competencies. The following table outlines the scientific literacy questionnaire.

Table 1. Scientific Literacy Questionnaire Grid

Aspects	**Indicators**
Attitude	Interest in science and technology
	Science as a way of knowing
	Student information related to science careers
	Learning preparation for science careers
Context	Concern for the sustainability of natural resources and the environment
	Sense of responsibility for protecting the environment
Competence	Valuation of scientific inquiry
	Responsibility for the scientific approach to inquiry
	Criticism as a means to validity

(Source: OECD, 2019)

Data analysis

Data analysis followed the interactive model of Miles et al., (2014) which includes three flows: data condensation to select and simplify relevant information, data presentation in narrative and matrix form, and conclusion drawing and verification. Data validity was ensured through triangulation of sources (students, teachers, principals) and techniques (observation, interviews, questionnaires). Questionnaire data were categorized into high, medium, and low levels based on the average score, then interpreted together with qualitative data from observations and interviews. This integration resulted in a complete and reliable picture of students' scientific literacy profiles, including the achievements of each aspect and the contextual factors that influence them.

RESULT AND DISCUSSION

Results

Scientific Literacy Profile

Students' scientific literacy profiles were obtained through a scientific literacy questionnaire that measured three main aspects: attitudes, context, and competencies. The questionnaire was completed by 30 fifth-grade students. A summary of the questionnaire results is presented in Table 2.

Table 2. Summary of Scientific Literacy Questionnaire Results

Aspect	**Indicator**	**Average Score**
Attitude	Interest in science and technology	3,25
	Science as a way of knowing	3,18

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	Student information related to science careers	2,85
	Preparation for science careers	3,17
Context	Concern for the sustainability of natural resources and the environment	3,18
	Sense of responsibility for protecting the environment	2,86
Competence	Appreciation for scientific inquiry	3,17
	Responsibility for the scientific approach to inquiry	3,29
	Criticism as a means to validity	3,08
Average		3,16

(Source: Processed primary data, 2026)

The data shows a gap between aspects: the indicator of responsibility for the scientific approach recorded the highest score (3.29), while information on science careers (2.85) and a sense of responsibility for protecting the environment (2.86) ranked lowest. Observations of the science learning process revealed that students lacked enthusiasm, had difficulty expressing ideas in problem-solving, and tended to simply follow teacher instructions without innovation. Teachers dominated as the primary source of knowledge, while interactive and technology-based learning media were minimally used. In one discussion session on rice field ecosystems, students demonstrated the ability to analyze biotic-abiotic relationships, formulate questions, record data, and relate these to community behavior. However, these activities were not supported by adequate scientific literacy assessment instruments. This is in line with the statement of a fifth-grade teacher in an interview:

"In my class, science learning relies more on conceptual assessment tools found in textbooks. Furthermore, I often assign students tasks to identify the causes and solutions to science problems in their environment."

However, in certain sessions, teachers facilitated scientific literacy-based discussions. Observations showed that students began analyzing the relationship between biotic and abiotic components in the rice field ecosystem, formulating questions, conducting observations, and recording data. Furthermore, students linked the discussion results to local community behavior in maintaining ecosystem balance, which was reflected in their environmental stewardship. However, these activities were not supported by adequate scientific literacy assessment instruments. Teachers acknowledged their limitations in developing test instruments, as they expressed:

"In my class, science learning uses conceptual assessment instruments listed in the textbook. Furthermore, I tend to give students assignments to find the causes and solutions to science problems in their environment."

Teachers acknowledged their lack of ability to develop instruments that specifically measure their ability to explain phenomena scientifically, evaluate investigations, and interpret data. A survey of 47 elementary school teachers in Kulonprogo Regency in April 2026 reinforced this finding; 51.5% of respondents stated that students' scientific literacy levels were still low. Three factors were identified contributing to the low scientific literacy. First, teachers' limited ability to develop scientific literacy assessment instruments beyond textbooks, resulting in assessments that do not fully encompass the dimensions of context, competency, and attitude. Second, the minimal use of interactive media; teachers rely solely on YouTube videos and encyclopedias without creating technology-based media that actively engage students. Third, project-based learning is rarely implemented due to limited time, tools, and materials, so the transmissive model remains dominant. From the student perspective, observations noted low motivation and self-confidence; students are reluctant to express their opinions, give up easily when faced with difficulties, and are not encouraged to explore alternative solutions.

Discussion

The gap between the high scores for responsibility for the scientific approach (3.29) and the low scores for science career information (2.85) and environmental responsibility (2.86) indicates that students' enthusiasm for inquiry procedures is not yet rooted in an understanding of the role of science in life and ecological concerns. This

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pattern indicates that learning has introduced scientific steps as routine, but has failed to foster an awareness of why science is personally and socially relevant. This lack of connection leads students to view science as a school activity separate from their identities and futures.

This finding aligns with a study at Seroja State Elementary School, which reported that although students' scientific attitudes were considered good, their scientific literacy skills were actually in the "poor" category (Dwiyanti et al., 2025). The gap in achievement between these aspects confirms that a positive attitude toward science does not necessarily guarantee adequate mastery of scientific literacy if it is not supported by strategies, models, and learning instruments that stimulate cognition and affect simultaneously. More broadly, scientific literacy in elementary schools has become a primary focus of global science education, as revealed in a study that found annual research growth of 10.02% with peak publications in 2024, as well as a strong link between scientific literacy, science education, and teacher education (Yuliana et al., 2025).

The current transmissive nature of science learning at Kalibawang State Elementary School, which places the teacher as the primary source of knowledge, reflects what (Lehesvuori et al., 2018) calls transmission modes of teaching, an authoritative teaching model in which student contributions are undervalued in classroom interactions. A student-centered approach, on the other hand, necessitates dialogue and active engagement to foster authentic scientific understanding. Nicolás-Castellano et al., (2023) demonstrated that the transition from transmissive to guided inquiry-based teaching in elementary schools requires a sustainable professional development plan involving all stakeholders, from teachers and principals to families. The lack of a paradigm shift from transmissive to constructive learning at Kalibawang State Elementary School has resulted in students acting passively, lacking enthusiasm, and simply following instructions without innovation.

This condition can be theoretically explained through the lens of self-determination theory (SDT) proposed by Ryan dan Deci (2000), where failure to meet the three basic psychological needs of autonomy, competence, and relatedness will weaken students' intrinsic motivation. When teachers dominate and students lose their autonomy in learning, their intrinsic motivation is eroded, resulting in boredom, a tendency to give up easily, and a reluctance to express opinions. Conversely, learning environments that support autonomy have been shown to be significantly related to students' engagement and academic achievement in science (Soe et al., 2025).

The low sense of environmental responsibility (2.86) indicates that science learning has not yet addressed the sustainability dimension as emphasized in the PISA 2025 framework, which promotes the concept of Agency in the Anthropocene (OECD, 2025). This concept demands that science education equip students with the capacity to understand and act on evidence-based environmental issues. The fact that this aspect ranked lowest, along with information on science careers, highlights the missing link between the content taught, personal relevance, and global urgency. Practically, integrating current environmental issues into science projects is an urgent need so that students see science as a tool to contribute to solving real-world problems.

Teachers' limitations in developing scientific literacy assessment instruments beyond textbooks reflect their weak pedagogical content knowledge (PCK) in the assessment component. Teachers are capable of teaching content but are unable to design measurement tools that capture the ability to explain phenomena, evaluate investigations, and interpret data. Consequently, teacher training must shift from simply mastering material to developing skills in constructing authentic assessment instruments.

Rahmaniati et al., (2025) revealed that an authentic digital assessment instrument based on a project-based STEM approach successfully produced an instrument with very high validity (97% for content experts, 94.5% for assessment experts, and 95.5% for media experts) and proven effectiveness in increasing the average student score from 58.2 to 83.2 (N-Gain 0.59). This kind of valid and reliable instrument allows teachers to map student abilities more precisely, identify specific gaps, and design targeted interventions. Instrument validation in a more basic context, the assessment of science process skills for prospective elementary school teachers also showed that mastery of skills such as asking questions, identifying variables, taking measurements, and interpreting data still needs significant improvement (García-Carmona et al., 2024). This finding is relevant to explaining why teachers at Kalibawang Public Elementary School have not been able to develop scientific literacy instruments independently; the root of the problem can be traced to the teachers' own weak mastery of science process skills.

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The limited use of innovative and technology-based learning media also explains the low student engagement, which is evident in boredom and a lack of enthusiasm. Teachers rely solely on YouTube videos and encyclopedias, without developing truly interactive media. Theoretically, the social constructivist approach (Maghfiroh & Muttaqin, 2025; Vygotsky, 1978) emphasizes that knowledge is constructed through social interactions mediated by language and cultural tools, including technology. Interactive digital media in the context of contemporary science education functions as scaffolding that bridges students' zone of proximal development, enabling them to achieve higher levels of understanding through guided exploration (Handayani, 2025). When interactive media is unavailable, this mediation process is interrupted, leaving students relying solely on verbal transmission from the teacher without the opportunity to construct knowledge independently.

Several recent studies support this argument. Pinasti dan Pratiwi (2025) developed interactive digital media that combined audio, quizzes, animations, and simulations, with 94% expert validation and 92% effectiveness in small-group trials and 96% in large-scale trials. Furthermore, Lestari dan Rohmani (2025), through the development of GENSEN, a Genially-based interactive media integrated with the PjBL-STEM model, reported an increase in students' average scientific literacy from 51.5 to 88.6 with an N-Gain of 0.76 (high category). These findings confirm that interactive media integrated with project-based learning models have a greater impact because they encourage students to actively explore concepts and apply them in real-world contexts.

The scarcity of project-based learning (PjBL) models in Kalibawang Public Elementary School, due to limited time, tools, and materials, further exacerbates the situation. Without learning experiences that provide space for independent design, testing, and revision of solutions, students' ability to explore alternative problem-solving strategies will not develop. In a large-scale study of 781 third-grade students Miller et al., (2025), they showed that cognitive flexibility, the ability to recognize diverse ideas as possible solution paths developed through PBL, significantly predicted science achievement ($\beta = 0.269$, $p < 0.001$) and literacy ($\beta = 0.489$, $p < 0.001$). This finding is highly relevant to the situation of Kalibawang Public Elementary School students who often exhibit ideas deadlock and only act according to instructions. The STEAM-PjBL model has also been shown to significantly improve students' scientific literacy through contextual projects that integrate science, technology, engineering, art, and mathematics (Suryanti et al., 2024). Meanwhile, the research trend of PjBL in elementary schools continues to grow and is closely integrated with STEM and scientific literacy (Suhardi et al., 2025).

The various factors causing low scientific literacy mentioned above do not stand alone but are interconnected. A study of determinant factors by Syofyan et al., (2025) on 513 elementary school students in Jakarta using structural equation modeling (SEM) proved that scientific literacy is positively and significantly influenced by internal factors including motivation, interest, and self-efficacy as well as external factors including classroom climate, learning quality, and parental support ($p = 0.000$). This finding reinforces the picture at Kalibawang Public Elementary School: low student self-efficacy and motivation (internal factors) interact with the quality of learning that is still teacher-centered and minimal media support (external factors), thus creating a vicious cycle that suppresses scientific literacy achievements. Specifically, Juniarso and Sulistyawati (2022) found that self-efficacy contributed 26.2% to elementary school students' scientific literacy, emphasizing that students' confidence in learning science is an important determinant that cannot be ignored.

Scientific literacy at the elementary school level is also understood as a process influenced by social and cultural dimensions. A systematic review by Roy et al., (2025) of empirical studies from three international databases confirmed that the development of scientific literacy in children is influenced by various factors, including educational institutions, play activities, educators' perceptions, and social and cultural factors. Limited teacher perceptions and capacity in developing learning instruments and media are the main obstacles, while social and cultural support from the school and family environment has not been optimized. Therefore, the necessary interventions must be systemic: improving teacher competence in developing instruments and media, encouraging the implementation of active project-based learning models, and building a learning ecosystem that supports the growth of students' science identity from an early age.

Therefore, a single intervention will not be effective. Integrated measures are needed, including teacher training in assessment and digital media, the provision of simple technological infrastructure, school policies that allow for integrated projects, and the development of mission-based educational games that simultaneously measure and stimulate all three dimensions of scientific literacy. These educational games provide a contextual solution that bridges the pedagogical needs and characteristics of digital native students, while maintaining the balance between entertainment and depth of content, as emphasized by (Prensky, 2021).

CONCLUSION

This study revealed that the scientific literacy profile of fifth-grade students at Kalibawang Public Elementary School was in the adequate category, with striking disparities between dimensions: scientific responsibility competency scored the highest, while science career information and environmental responsibility scored the lowest. This low achievement was caused by three interrelated factors: teachers' limited ability to develop assessment instruments beyond textbooks, a lack of interactive media, and the dominance of a transmissive model that discourages project-based learning.

The primary contribution of this study lies in the simultaneous mapping of these three dimensions of scientific literacy at the elementary school level, a practice rarely undertaken, and the identification of systemic interrelationships among these contributing factors. Based on these findings, this study proposes a contextual solution in the form of a mission-based educational game that has the potential to measure and stimulate aspects of knowledge, competency, and attitude in an integrated manner. Practically, the study results provide an empirical basis for developing teacher training programs in developing digital instruments and media, and encourage school policies to allocate time for integrated STEM projects on a regular basis.

However, this study has limitations, particularly the use of a single-case study design that limits the transferability of the findings, the relatively small sample size, and the measurement of scientific literacy that relies solely on self-report questionnaires and observations without performance tests. Further research is recommended to develop a prototype mission-based educational game and test its effectiveness through an experimental design in several elementary schools with diverse characteristics. Furthermore, future studies should longitudinally investigate the impact of teacher training in digital assessment and project-based learning on sustainable improvements in students' scientific literacy.

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