Analysis of Science Literacy Skills of Prospective Teacher Students using Project-Based Learning Model Based on TPACK

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Abstract. The PISA results indicate that the standard of literacy in Indonesia requires enhancement; thus, it is imperative to elevate the proficiency of both current and future educators to ensure they are both professional and capable. In the 21st century, scientific literacy serves as a crucial element for aspiring educators, as it enhances critical thinking and addresses contemporary challenges. This research endeavors to examine the scientific literacy competencies of future educators by employing the TPACK (Technological Pedagogical Content Knowledge) framework within a Project Based Learning (PjBL) instructional model. This research employs a quantitative descriptive methodology, focusing on a cohort of 23 prospective elementary school teachers from IAIN Lhokseumawe. Data collection was conducted through science literacy assessments and observational techniques. The findings indicated that proficiency in scientific literacy encompasses dimensions of content, methodology, and contextual understanding. The test results indicated that the proficiency in scientific literacy regarding content was classified as sufficient (62.5%), while the process aspect achieved a good rating (82.6%), and the context aspect also fell within the good category (71.6%). Furthermore, these findings were corroborated by the attitude assessment, revealing that 70% of students were rated as good, 13% as very good, and 17% as sufficient. The implementation of the TPACK-based PjBL model significantly enhances the science literacy skills of prospective teacher students. Beyond merely grasping scientific concepts, students demonstrate the ability to apply these concepts within the framework of projects that resonate with real-life contexts. The presence of technology significantly enhances the educational experience for students and fortifies essential skills pertinent to the 21st century. The findings suggest that the implementation of the TPACK-based Project Based Learning model for prospective teacher students yields positive and effective outcomes.

Keywords: Science Literacy, Project Based Learning models, TPACK, Teacher Candidates

1 Introduction

In light of the swift advancements, particularly in technology and information, it is imperative to implement reforms in the educational sector. Initiatives can be undertaken to cultivate human resources that are informed and possess substantial expertise to facilitate national growth. Developing literacy skills, particularly science literacy, is crucial as it equips

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children to adapt to numerous life changes. The provision and execution of quality education influence national development outcomes. The transition process requires help from educators who are experts in their disciplines and possess 21st-century abilities.

The science learning process in the 21st century has transitioned to a student-centered approach that can be enhanced through science literacy education. The efficacy of science literacy education is evidenced by students' comprehension of scientific concepts and their capacity to address diverse real-life challenges [1]. Scientific literacy refers to an individual's capacity for critical thinking, problem-solving, and decision-making grounded in an understanding of scientific concepts, which are essential abilities in today's globalized and technological landscape.

The 2022 PISA (Program for International Student Assessment) survey results indicated an increase in the average science proficiency score of Indonesian students, reaching 383 (with an average score of 384) [2]. However, Indonesia ranked 67th out of 81 participating countries in the science category for PISA 2022 [3]. The TIMSS (Trends in International Math and Science) survey indicates that merely 5% of Indonesian pupils can tackle high-level issues necessitating sound reasoning, whereas 95% predominantly engage in rote memorizing of low-level topics [4]

Preliminary data and prior research indicate substantial disparities in science literacy skills, evidenced by variations in students' performance on assigned science tasks and test outcomes. When presented with high-level thinking science questions, the average score achieved is 74. The findings of this preliminary observation are corroborated by multiple studies indicating that the scientific literacy skills of prospective teacher students are predominantly at a satisfactory level, with some exhibiting proficiency. Numerous influencing factors encompass educational background, learning styles, instructional methods employed by lecturers, and student engagement in acquiring new knowledge and participating in various activities [5], [6].

Scientific literacy is an essential competency that student teachers must acquire, as they are obligated to comprehend scientific concepts and effectively impart this knowledge to future generations. In the age of globalization and swift technological progress, scientific literacy is becoming progressively vital due to the challenges confronting society today, including health, environmental, and technological concerns. Consequently, cultivating scientific literacy abilities in future educators is a paramount concern in education.

Science literacy abilities can be enhanced by the application of appropriate learning methodologies or frameworks. The project-based learning approach is one applicable educational framework. The project-based learning strategy can engage students in authentic projects pertinent to scientific subjects. Through Project-Based Learning (PjB), students acquire theoretical knowledge while simultaneously cultivating the skills to create, execute, and present scientific solutions to encountered challenges [7], [8]. The use of the PjBL learning paradigm is anticipated to enhance scientific literacy as students are motivated to apply scientific principles, engage in collaboration, and cultivate critical thinking abilities (Muhibbuddin et al., 2020).

Project-based learning is a learning model that focuses on students' ability to respond to real-world questions or challenges through an extended inquiry process. There are several studies that suggest the impact of applying the PjBL model for students and the role of teachers in its implementation. Hossein et al [10] in their research suggested that by implementing the PjBL learning model, students accompanied by teachers can make the final product (Producer Project); enjoy their knowledge or experience (Consumer Project); improve techniques or skills, namely the ability to solve intellectual problems, especially related to projects, strengthen skills, multidisciplinary and also be able to integrate values such as cooperation, organization, and time management in a practical way.

Several studies have demonstrated that the PjBL learning model can enhance students' analytical skills and comprehension in comparison to conventional learning methods. This demonstrates students' capacity to effectively analyze scientific information, formulate hypotheses, and solve problems. The results of other studies have shown that the application of the appropriate learning model can enhance science literacy skills. In addition to mastering the fundamental concepts of science and solving problems related to the context of science, prospective teacher students are expected to be able to equip students with the skills necessary to confront future challenges. Technology integration, or the TPACK approach, can be advantageous when employing the TPACK-based project-based learning model [11], [12].

In numerous studies, it was discovered that TPACK has been incorporated into the learning process, with a particular emphasis on the teacher's capacity to select the appropriate material and technology for the learning process. Additionally, the TPACK skills that teachers possess are superior to those of other individuals, particularly in the areas of TK, TCK, and TPK [13], [14]. Additionally, Dinara Joldanova et al [15] asserted that the integration of TPACK into the learning process can lead to an increase in student motivation and self-efficacy. This is due to the fact that technology enables students to access teaching materials that are tailored to the subject matter. Additionally, it has an impact on the development of self-confidence, social skills, and communication abilities.

The TPACK approach is particularly significant in assessing the level of comprehension of potential teachers regarding technology. Effective teaching can be achieved through the proper interaction between the domains of technology, pedagogy, and knowledge of the content of learning materials, as well as the presence of prospective teachers' comprehension of the use of technology that is pertinent to science content [16]. In a separate study, it was discovered that TPACK can significantly enhance the efficacy of prospective science, mathematics, and social studies teachers and can be integrated with the pedagogical abilities of prospective teachers to explain the learning material studied [17].

This research aims to investigate the scientific literacy competencies of prospective elementary school teachers through the TPACK-based project-based learning approach. Implementing project-based learning is anticipated to positively influence science literacy skills, namely the capacity to assess problems, devise solutions, resolve issues, and effectively explain the resulting products. During the project completion phase, particularly concerning scientific material, it will indirectly engage elements of content, process, and context. A comprehensive understanding of scientific material will enable prospective teacher students to identify the scientific products to be developed and enhance their scientific process skills, thereby facilitating the timely and relevant completion of the product in accordance with the designated scientific theme.

Analyzing the science literacy skills of prospective teachers might yield valuable recommendations for curriculum development and enhance teaching practices, so improving their preparedness for professional science instruction. To enhance the role of prospective teachers in cultivating a generation that is critical and capable of scientific thinking. Furthermore, the findings of this science literacy analysis will facilitate prospective teachers' comprehension of the obstacles encountered and the measures required to enhance the quality of science instruction in schools subsequently.

The researchers aim to conduct a more in-depth analysis of the science literacy skills of prospective teacher students, focusing on content, process, and context within science courses, utilizing the TPACK-based project-based learning model.

2 Research Method

Qualitative descriptive research methodologies are implemented in this investigation. This qualitative research method generates descriptive data in the form of written or spoken words from individuals and observable behavior. It is characterized by a holistic natural background, the use of humans as research tools, the inductive analysis of data, and a greater emphasis on the process than the results of the research, as agreed upon by the researcher and the research subject [18]. Descriptive qualitative is a research method that is based on the philosophy of post-positivism and is employed to investigate natural object conditions [19]. The researcher serves as the primary instrument in this approach, and the results will provide a more detailed explanation of the issues at hand by examining an individual, group, or event as closely as possible.

As many as 23 first-semester students from the Department of Madrasah Ibtidaiyah Teacher Education (PGMI) IAIN Lhokseumawe were the subjects of the investigation. Science literacy assessments and questionnaires are implemented as methodologies for data acquisition. Table 1 displays the lattice of the science literacy test instrument, while Table 2 displays the questionnaire lattice of student attitudes toward science literacy.

Table 1. Framework of the Science Literacy Assessment Tool

No	Aspects	Indicator	Number of Question Items
1	Content	Recall and apply relevant scientific knowledge.	1,2
		Identify, use and produce clear and representative models.	3,4
		Identify the questions explored in a given scientific study	5,6
2	Process	Identify scientific opinions	7, 8
		Propose a clear hypothesis	9
		Make and justify appropriate predictions	10,11
		Evaluate how to scientifically explore a given question 4.	12,13
		Transforming data from one representation to another	14,15
3	Contexs	Contains scientific phenomena to explain everyday phenomena	16,17
		Contains links between science and everyday phenomena	18,19
		Applying science in the use of natural resources	20

Table 2. Framework for the Science Literacy Attitude Questionnaire

No	Aspect	Indicator	Item Question
1	Content	Interest in science	6
2	Process	Assessing the scientific approach to investigation	8
3	Context	Environmental awareness	6

Descriptive and qualitative data analysis methodologies were implemented. In order to process the data collected from the research, descriptive analysis techniques were employed to compute scores based on the science literacy test scores, which were calculated using the following formula:

$$Value = \frac{Score\ obtained}{\text{Maximum score}} \text{ x } 100\%$$

The percentage result data is then converted into qualitative criteria, the criteria for creative thinking skills can be seen in table 3.

Table 3. Science Literacy Criteria

Total Score (%)	Science Literacy Criteria
86 – 100	Very good
76 – 85	Good
60 – 75	Fair
55 – 59	Poor
<54	Very Less

The data obtained from the questionnaire using a Likert scale is calculated with the following formula:

$$Value = \frac{Total\ score\ (F)}{\text{Maximum score (N)}} \text{ x } 100\%$$

The results of the answers (the percentage) can be categorized with the criteria as shown in table 4.

Table 4. Science Literacy Questionnaire Criteria

Total Score (%)	Science Literacy Criteria
0 – 20	Very Less
21 – 40	Poor
41 – 60	Fair
61 – 80	Good
81 – 100	Very good

Additionally, the qualitative data analysis method employed in this study is qualitative data analysis, with data validity assessed by the data triangulation methodology. Miles and Huberman [20] asserted that qualitative data analysis can be conducted in multiple stages, specifically:

a. Data Reduction entails summarizing, selecting essential elements, emphasizing significant aspects, and identifying themes and patterns. To facilitate a comprehensive understanding and simplify the process for researchers to gather additional data.
b. Data Presentation (Display Data) refers to the elucidation of data presentation in qualitative research, which can be executed through succinct descriptions, charts, inter-category relationships, flowcharts, and similar formats.
c. Drawing Conclusions, indicating that the preliminary conclusions presented remain provisional and will be subject to modification in the absence of compelling evidence to substantiate the subsequent data gathering phase. Conclusions in qualitative research may address the initial problem formulations; however, this is not guaranteed, as the problems and their formulations are provisional and may evolve during field research.

3 Result and Discussion

3.1 Result

This study employed a qualitative descriptive methodology to examine the scientific literacy competencies of prospective teacher candidates utilizing the TPACK-based project-based learning model. The preliminary procedure involved administering and evaluating science literacy test questions pertinent to scientific content for prospective teacher candidates. The outcomes of the creative thinking ability assessment in the science curriculum. Students in the subsequent stage were administered a questionnaire to assess their attitudes towards science literacy abilities following instruction in scientific content utilizing the TPACK-based PJBL paradigm. This study analyzes the indications of creative thinking: content, method, and context factors. The science literacy test results of prospective teacher students in science courses are presented in table 5.

Table 5. Results of Science Literacy Assessment

No	Student Code	Value			Total Score	Category
		Content	Process	Contexts		
1	M1	24	26	23	73	Fair
2	M2	24	37	22	83	Good
3	M3	24	43	17	84	Good
4	M4	24	37	22	83	Good
5	M5	24	37	17	78	Good
6	M6	24	37	22	83	Good
7	M7	24	37	17	78	Good
8	M8	24	42	22	88	Good
9	M9	24	38	18	80	Good
10	M10	13	32	17	62	Fair
11	M11	19	43	6	68	Fair
12	M12	24	31	22	77	Good
13	M13	19	38	12	69	Fair
14	M14	14	44	22	80	Good
15	M15	16	43	12	71	Fair
16	M16	24	32	22	78	Good
17	M17	16	37	23	76	Fair
18	M18	24	37	17	78	Good
19	M19	16	27	18	61	Fair
20	M20	19	31	17	67	Fair
21	M21	21	37	11	69	Fair
22	M22	16	37	28	81	Good
23	M23	24	37	17	78	Good
Average Value		**82,2**	**93,3**	**85**	**76,3**	**Good**

Based on the data in table 5, it is found that the science literacy skills of prospective teachers are at a good level with an average score of 76.3. Furthermore, to support the ability of science literacy, students were given a questionnaire to see the attitudes formed in science literacy, the results of the analysis can be seen in table 6.

Table 6. Results of Analysis of Student Science Literacy Attitudes

Assessment Criteria	Number of students	Science Literacy Attitudes (%)
Very good	3	13
Good	16	70
Fair	4	17

Table 6 shows that the percentage of achievement of the questionnaire related to the attitude of science literacy skills on the criteria of content, process and context obtained 3 students (13%) are in the criteria Very good, 16 students (70%) are in the good criteria and 4 students (17%) are in the sufficient criteria for the attitude of science literacy skills.

3.2 Discussion

The objective of this investigation is to evaluate the scientific literacy abilities of prospective teacher students in science courses by employing the TPACK-based project-based learning model. The science literacy skills of prospective teacher students are significantly enhanced by the application of the TPACK-based project-based learning model. This is evident in the active engagement of students in collaborative projects that require them to demonstrate critical thinking and comprehend the material from the perspectives of content, process, and context in science courses.

The scientific literacy ability test results were analyzed, and 14 students were classified as "good" and 9 students as "sufficient" based on the 20 questions that were administered in the science course. This indicates that there are no student scores in the "excellent" category. Additionally, the test results indicate that the average content aspect value is 82.2 (good), the process aspect is 93.3 (very good), and the context aspect is 85 (good). Consequently, the average student science literacy value is 76.3, classifying it as "good."

Previous studies indicated that students' scientific literacy skills remain inadequate, potentially due to their limited literacy abilities, particularly in science, which adversely affects their comprehension of advanced scientific questions. Additionally, the educators' competence in delivering creative and innovative instruction may also contribute to this issue (Rosiah).

A questionnaire was administered to assess students' attitudes towards their science literacy skills, incorporating indicator statements related to content, process, and context aspects of science literacy. The investigation revealed that 13% of students, equating to 3 individuals, demonstrated very strong science literacy skills. Additionally, 70% of students, or 14 individuals, fell into the good group, while 17%, representing 4 students, were classified in the sufficient category. The science literacy skills of students categorized as moderate and low can be affected by several factors, including interest, learning habits, curiosity, inadequate literacy skills, lack of awareness of current developments, and teaching methodologies employed by lecturers [5]. Students with a genuine interest in learning will concentrate and engage attentively, fostering curiosity and maximizing their comprehension of the content (Irwan et al., 2020).

The study results indicate that students exhibit strong talents in content, namely in memory retention, application, and the identification of models and problems for scientific exploration. Students demonstrate proficiency in identifying opinions, formulating hypotheses, and evaluating questions; yet, they exhibit deficiencies in data transformation. Moreover, it is evident that students' competencies remain adequate in the practical application of science in

daily life. This pertains to various studies indicating that the scientific literacy competence of prospective elementary school teachers is categorized as medium. Specifically, aspects related to scientific phenomena and the identification of scientific questions or issues are also classified as medium, while the utilization of scientific evidence is categorized as low [21], [22]. The findings of this study may serve as a reference for university learning growth, particularly in the selection of suitable pedagogical approaches and models, ultimately producing competent prospective instructors proficient in essential 21st-century skills.

The PjBL model is a learning approach in which students learn through a process that focuses on completing real projects that are relevant to their life or profession. In the context of prospective teachers, PjBL allows them to integrate theory and practice by engaging directly in projects, students will understand how to apply educational theories to real situations. In addition, the completion of the project through group discussions can improve collaboration skills, thus improving cooperation and communication skills [23].

The application of the TPACK framework in Project-Based Learning enables student instructors to comprehend and cultivate the capacity to investigate scientific concepts thoroughly through the integration of suitable technology in education. Enhancing scientific literacy among science educators is a crucial element in fostering high-quality science education that cultivates pupils with scientific literacy competencies [24], [25],

PjBL learning grounded in TPACK can positively influence the science literacy competencies of prospective teachers, enabling them to select and employ technology pertinent to scientific concepts, facilitate the exploration of creative and innovative ideas, and assist students in locating references or tools to enhance their projects [26], [27]. The student-centered learning process allows students the autonomy to investigate multiple solutions to project-related challenges. Collaboration and discussion facilitate the exchange of ideas, fostering a broader perspective and stimulating creative thinking through interaction interaksi [28].

The project-based learning model enhances the competence of prospective teacher students, as evidenced by their improved performance in understanding science content, designing and completing assigned science projects through worksheets, and effectively presenting their work to peers. Professional competence enhances teacher performance, thereby contributing to the quality of education. The effectiveness of teacher work should align with educational objectives [29], [30]. The appropriate model, particularly project-based approaches like STEM-Project in science education, enables students to analyze problems and identify solutions comprehensively (Amiruddin).

In numerous additional studies, it was discovered that the integration of PjBL and creative teaching can surmount numerous obstacles during the pandemic to accomplish learning objectives by fostering and motivating social relationships, particularly in science learning that employs technology (virtually). In addition, prospective teacher students can enhance their science literacy skills by modifying the pertinent curriculum to be output-based, as well as by conducting straightforward practicums and utilizing technology effectively[31].

Consequently, the findings indicated that the development of a project-based learning paradigm based on TPACK was feasible and received a favorable response from prospective teacher students. Furthermore, the science literacy skills of prospective teacher students in basic education are positively affected by the TPACK-based project-based learning model, although the effect is not yet significant.

4 Conclusion

Following the analysis of research and discussions concerning students' science literacy skills within science courses utilizing the TPACK-based project-based learning model, it is evident that students' science literacy skills are categorized as good, with an average score of 76.3. Specifically, the average score for the content aspect is 82.2, classified as good, while the process aspect achieves an average score of 93.3, categorized as excellent. The context aspect also reflects a commendable average score of 85, placing it in the good category.

The findings are further corroborated by the outcomes of interviews and documentation pertaining to project reports and MFIs completed by students. The findings regarding flexibility indicate that students can address problems with multiple solutions; however, the solutions presented lack sufficient detail. In the context of novelty, this creative thinking ability indicates that students are beginning to generate innovative ideas for addressing problems through unique approaches. The collaboration aspect indicates that most students have successfully engaged with the team. Through the project-based learning model, prospective teacher students gain a comprehensive understanding of the material, particularly in the field of science. Additionally, students develop the skills to design simple projects, create reports, and deliver presentations. Furthermore, students can effectively utilize appropriate technology to complete the assigned project, which may serve as a foundation for future implementation in science education within elementary schools.

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