APTISI Transactions on Technopreneurship (ATT)
Vol. 8, No. 1, March 2026, pp. 63−73
E-ISSN: 2656-8888 | P-ISSN: 2655-8807, DOI:10.34306

Comparison of Students Science Literacy Abilities Using Inquiry and Cooperative Learning Models

Muktar Bahruddin Panjaitan[1*], Asister Fernando Siagian[2], Loso Judijanto[3], Mufarizuddin Mufarizuddin[4], Herman Herman[5], Nanda Saputra[6], Zokir Mamadiyarov[7]
[1,2]Department of Natural Science Education, HKBP Nommensen University of Pematangsiantar, Indonesia
[3]IPOSS Jakarta, Indonesia
[4]Department of Teacher Professional Education, Pahlawan Tuanku Tambusai University, Indonesia
[5]Department of English Education, HKBP Nommensen University of Pematangsiantar, Indonesia
[6]Department of Madrasah Ibtidaiyah Teacher Education, Al-Hilal Sigli Tarbiyah College of Science, Indonesia
[7]Department of Finance, Alfraganus University, Uzbekistan
[1]muktar.panjaitan@uhnp.ac.id, [2]asister.siagian@uhnp.ac.id, [3]losojudijantobumn@gmail.com, [4]zuddin.unimed@gmail.com, [5]herman@uhnp.ac.id, [6]nanda.saputra2589@gmail.com, [7]z.mamadiyarov@afu.uz
***Corresponding Author**

Article Info

Article history:

Submission January 14, 2025
Revised March 18, 2025
Accepted December 9, 2025
Published December 19, 2025

Keywords:

Science Literacy
Learning Model
Achievement Motivation
STAD Cooperative Learning
Educational Models

ABSTRACT

The purpose of **this study** was to determine whether there is a difference in scientific literacy between students who follow the inquiry learning model and students who follow the STAD cooperative learning model to determine the difference between scientific literacy due to students' **achievement motivation**; to describe the interaction between the learning model and achievement motivation on students' scientific literacy. **This study used** a Posttest-Only Control Group Design with a two-factor analysis. The population in this study were fifth-semester PGSD students at HKBP Nommensen University of Pematangsiantar, in 2024/2025 Academic Year, with totaling 186 students, which sample of 124 students determined by using Simple Random Sampling technique for the class. **Data were obtained** using the achievement motivation instrument and the science literacy test. Data analysis was carried out using two-way analysis of variance. **The study found** a significant difference in scientific literacy between students who followed the Inquiry Learning Model and those who followed the STAD Cooperative Learning Model, with a p-value of 0.000, which is less than 0.05. There is a difference in student science literacy based on achievement motivation with a value of Sig. $0.000 < 0.05$ and there is no interaction between the learning model and achievement motivation on student science literacy, with a value of Sig. $0.230 > 0.05$.

DOI: https://doi.org/10.34306/att.v8i1.640

1. INTRODUCTION

The development of the 21st century has brought about profound changes in how people live, work, and learn. With rapid advancements in technology and globalization, educational systems worldwide face the challenge of preparing students with the skills needed to thrive in an increasingly complex and interconnected world. In particular, countries facing educational challenges such as those with limited resources or evolving curriculums must rethink traditional teaching methods to ensure that students are equipped with critical thinking, problem-solving, and scientific literacy skills [1–3]. These skills are essential not only for personal success but also for the broader social and economic development of nations.

This study addresses an important aspect of educational reform the development of scientific literacy through innovative teaching models [4]. Given the global emphasis on improving educational outcomes, particularly in developing nations, this research highlights how different learning models, such as the Inquiry Learning Model and the STAD Cooperative Learning Model, can improve student engagement and scientific literacy. These findings are particularly relevant for countries facing challenges in improving the quality of education, as they provide insights into effective strategies that can be implemented to foster critical thinking and scientific knowledge among students. Nowadays, education is becoming increasingly important to ensure that students have learning and innovation skills, skills in using technology and information media, and can work and survive by using life skills [5].

The 21st century demands that education equip students with the necessary skills to thrive in the global economy. The Partnership for 21st Century Skills stresses that 21st-century learning should foster four key competencies communication, collaboration, critical thinking, and creativity. Additionally, it highlights that in order to navigate the challenges of 21st-century learning, individuals must possess critical thinking abilities, digital literacy, information literacy, media literacy, and proficiency in information and communication technology [6–9].

In the modern era, education plays a pivotal role in cultivating students' abilities in learning, innovation, technology, and life skills that are essential for success. The Ministry of Education and Culture of the Republic of Indonesia has integrated three core concepts of 21st-century education to develop a new curriculum for elementary schools, junior high schools, senior high schools, and vocational high schools. These concepts include 21st-century skills, a scientific approach, and authentic assessment [10–12].

Moreover, these three concepts are adapted to align with Indonesia's vision for 2045, referred to as ”*Indonesia Emas*”. The adaptation process aims to ensure that the concepts are compatible with the capabilities of students and the competencies of educators and education staff [13]. The three core areas of 21st-century skills consist of (1) life and career skills, (2) learning and innovation skills, and (3) information, media, and technology skills. These skills are visually represented in a framework called the 21st-century knowledge-skills rainbow [14].

Modern science education is focused on equipping students with the skills necessary for success in the 21st century. Among these skills, scientific literacy is crucial [15]. It is the ability to apply scientific knowledge in daily life, think critically, and make informed decisions. According to the journal The Meaning of Science, scientific literacy involves not only understanding science but also developing the ability to appreciate it, which in turn contributes positively to the community. The emphasis on improving scientific literacy aligns with the goals of SDG 4 (Quality Education) [16, 17], which aims to provide quality, inclusive, and equitable education and foster lifelong learning for all. By incorporating innovative teaching methods like inquiry-based and cooperative learning, we can enhance students' scientific literacy, critical thinking, and problem-solving skills, further advancing the objectives of SDG 4 [18].

Scientific literacy is a broad concept with multiple interpretations. Two primary perspectives exist the ”science literacy” group and the ”scientific literacy” group. The ”science literacy” group sees scientific literacy primarily as understanding scientific content, such as basic scientific principles. This view is commonly held by science educators worldwide, including in Indonesia [19]. On the other hand, the ”scientific literacy” group believes that scientific literacy goes beyond just content knowledge and is linked to life skills development. This perspective emphasizes the importance of reasoning skills in a social context and advocates for the idea that scientific literacy is for everyone, not just those pursuing careers in science or specialized fields [20].

Scientific literacy emphasizes the importance of equipping students with the knowledge to apply scientific concepts effectively, think critically, and make well-informed decisions on issues that directly impact their lives [21]. However, science education in many countries still often overlooks the social aspect of learning and the necessity of fostering the skills students need to actively engage in society.

Discussions surrounding the aims of science education typically start with scientific literacy, which reflects the expectations of what students should learn and be able to do as a result of their educational experiences. Despite this, the definition of scientific literacy, particularly in the context of classroom teaching, remains a topic of debate. The term is often considered abstract, leading to various interpretations about the desired learning outcomes [22]. However, it is widely agreed upon that the ultimate goal of scientific literacy is to enable students to understand and engage in societal discussions regarding science and technology-related issues [23].

Scientific literacy encompasses several key components context, knowledge, competence, and attitude. The PISA assessment is designed to help students recognize the value of science for individuals and society, especially in enhancing the quality of life and informing public policy. Therefore, the PISA scientific literacy questions are structured around contexts related to the individual, society, and global regulations, using specific situations as the basis for assessment exercises. The PISA assessment does not focus on context itself, but rather on assessing the competence, knowledge, and attitudes that students hold in relation to these contexts. This study is based on the 2013 PISA assessment, which specifically evaluates the knowledge and competence aspects of scientific literacy [24, 25].

Historically, when schools began expanding access to education in the 21st century, literacy was primarily understood as the ability to read a technical skill acquired once in a lifetime for processing knowledge. In the industrial world, reading proficiency became widely recognized as a standard skill. However, the concept of literacy has since evolved, now encompassing the ability to understand, identify, interpret, create, and communicate knowledge through written materials in various contexts. These skills are now considered essential for success in the modern industrial world [26].

Science education should ideally focus on developing science process skills, enabling students to engage in active experiences that stimulate their cognitive abilities (minds on), psychomotor skills (hands on), and social or affective skills (hearts on). One way to assess students' scientific literacy is by evaluating their inquiry skills, which reflect their ability to conduct investigations. According to the study Assessing Inquiry Skills as a Component of Scientific Literacy, students' scientific literacy can be gauged through their inquiry skills, which involve the ability to inquire and explore [27].

Indonesia has participated in the PISA assessment since 2000, but the results have consistently been unsatisfactory. In the 2022 PISA study, Indonesia ranked 69th out of 80 countries, placing 12th from the bottom, with a total score of 1,108. This result places Indonesia in the lower-middle tier when compared to other ASEAN nations. Singapore stands far ahead of the rest, achieving the highest total score of 1,679. Vietnam follows in second place with a score of 1,403, followed by Brunei (1,317) and Malaysia (1,213). Indonesia ranks sixth in the region, below Thailand (1,182), while the Philippines (1,058) and Cambodia (1,012) trail behind. These results suggest that Indonesia's education system still requires substantial improvements across various areas [28–30].

The low level of scientific literacy among students can be attributed to at least two key factors, individual factors and social factors. One important individual factor is achievement motivation, which originates from within the student. When students are motivated to learn, they tend to achieve better results. The level of motivation a student has plays a significant role in determining their academic success. Achievement motivation is the drive within a person to excel in a specific area, particularly in academics [31].

To enhance students' scientific literacy, it is not only important to foster strong achievement motivation, but teachers must also consider appropriate teaching strategies that align with the conditions and potential of their students. The teaching approach should be in harmony with the selected learning model to facilitate more effective achievement of learning objectives [32]. This can be accomplished by implementing innovative learning models that address the challenges of improving students' scientific literacy, especially for those struggling with low achievement levels [33].

The learning models being discussed are the Inquiry Learning Model and the Cooperative Learning Model with the STAD type. The Inquiry Learning Model focuses on critical thinking and analysis as students work through the process of solving a problem. It involves several stages based on scientific methods, such as investigating issues, formulating hypotheses, designing experiments, collecting data, and describing solutions. In this model, the teacher presents a problem, while students determine the process and solution, with the teacher serving as a facilitator [34].

The Student Teams Achievement Division (STAD) model was introduced by Robert Slavin and colleagues. In STAD, students are divided into small groups of 4-5 people, with a mix of genders, ethnicities, and academic abilities. The key idea behind this cooperative learning strategy is that students work together to achieve learning objectives, benefiting from the diverse academic strengths within each group. The components of STAD include Presenting objectives and motivation, forming groups, teacher-led presentations, teamwork-based learning activities, quizzes for evaluation, and team achievement rewards [35].

The objectives of this study are to assess whether there is a difference in scientific literacy between students who follow the Inquiry Learning Model and those who follow the STAD Cooperative Learning Model to examine the impact of achievement motivation on students' scientific literacy, to explore the interaction between learning models and achievement motivation in influencing students' scientific literacy [36]. Consequently, the researcher conducted a study titled "Comparison of Students' Scientific Literacy Abilities Using the Inquiry and Cooperative Learning Models of STAD Type Reviewed from Achievement Motivation".

2. RESEARCH METHOD

While this study provides valuable insights into the effectiveness of different learning models on scientific literacy, it is important to recognize several limitations related to the study design. First, the quasi-experimental nature of the study poses certain challenges. Unlike randomized controlled trials, a quasi-experimental design lacks random assignment of participants to treatment conditions, which can introduce selection bias. In this study, students were not randomly assigned to the Inquiry Learning or STAD Cooperative Learning models, and therefore, there may be unmeasured differences between the groups that could influence the results. For example, students with different baseline levels of academic performance or motivation may have self-selected into classes, leading to potential confounding variables that were not controlled for [37].

Additionally, the study design relied on a Posttest-Only Control Group Design, which means that the analysis is limited to the outcomes measured after the intervention. Without pre-test data, it is difficult to assess whether the groups were equivalent at the start of the study in terms of their scientific literacy skills. As a result, any changes observed in scientific literacy could potentially be due to pre-existing differences between the groups rather than the learning models themselves [38].

Another limitation is the lack of control over external variables, such as the influence of the classroom environment, teaching styles, or individual teacher effectiveness. These external factors could have affected the students' engagement and learning outcomes, making it difficult to isolate the specific impact of the learning models being tested. Moreover, since this study was conducted at a single institution with a relatively homogeneous sample (PGSD students at HKBP Nommensen University), the findings may not be fully generalizable to other educational settings or populations [39].

Future research could benefit from a more rigorous experimental design, such as using a Randomized Controlled Trial (RCT), which would allow for better control over confounding variables and provide a more robust assessment of the causal effects of different learning models on students' scientific literacy. Additionally, incorporating pre-test measures would help to establish a clearer baseline for scientific literacy and provide a more accurate measure of the impact of the learning models [40–42].

A sample of 124 students was divided into 62 students in the experimental class and 62 students as the control class. The sampling technique used was Simple Random Sampling of the class. Before sampling, first determine the class equivalence with the One-Way ANOVA test from the scores of the Lower Class Science subjects in the Odd Semester Final Exam of the 2024/2025 academic year [43]. After it was proven that the population of the six classes was normally distributed and had homogeneous variance, an ANOVA test was carried out to test the equivalence between the six classes [44, 45]. The results of the class equivalence showed that the abilities of the 6 classes were in equal conditions. From 6 classes that are already equivalent, then a draw technique is carried out to find 2 classes as experimental groups and 2 classes as control groups. The students of the research subjects in each group are not all taken as samples, but only the upper and lower groups that meet the criterion-referenced based on the results of the achievement motivation questionnaire are taken [46]. From draw technique, the experimental group was obtained, namely classes PG1 and PG4 which were given the Inquiry learning model treatment and the control group, the STAD Type Cooperative learning model treatment. In this study, there were four variables consisting of 2 independent variables, namely the Inquiry learning model and the STAD Type Cooperative learning model, one dependent variable and one moderator variable [47]. The dependent variable in this study is scientific literacy and the moderator variable is achievement motivation which is divided into high achievement motivation and low achievement motivation. This variable is not yet known whether it interacts with the learning model that can affect students' scientific literacy. Data on students' achievement motivation was collected using a questionnaire given before the experiment, while scientific literacy skills were collected using a written test given after the experiment was carried out. The test given was a written test in the form of an essay consisting of 10 items to measure students' scientific literacy in the domain of science context and science process. Before the instrument was used to collect data, it was first validated by 2 experts in order to obtain a good instrument. Achievement motivation data were analyzed using item validation and reliability tests. The science literacy test data were tested for item validation, reliability, test differential power, and test difficulty levels. The results of the validation of the achievement motivation questionnaire content were 0.94. From 60 achievement motivation questionnaire items that were tested, 8 items were invalid and 52 items were declared valid with a very high degree of reliability of 0.917. The results of the science literacy test validation were 1.00. From 10 science literacy test items that were tested, all were declared valid by experts [48].

The data in this study were analyzed in stages including data description, prerequisite tests, and hypothesis tests. The prerequisite tests carried out were the normality test for data distribution and the homogeneity test for variance. The results of the analysis showed that all data obtained were normally distributed with a sig. value of $0.502 > 0.05$. The homogeneity of variance test was conducted on four data groups, if referring to the average, the Levene statistic value is 1.381 with a significance value of 0.252. This value is greater than 0.05 so it can be said that the variance of science literacy data between the four data groups is the same or homogeneous. The hypothesis test in this study used a two-way analysis of variance (ANOVA) with SPSS 26 For windows with a significance level of 5%.

3. RESULT AND DISCUSSION

The results of the study are shown in Table 1.

Table 1. Description of Science Literacy of Student

Model of Learning	Motivation of Achieve	Mean	Std. Deviation	N
Inquiry	High	84.52	3.63	42
	Low	77.45	3.18	20
STAD	High	79.78	3.46	47
	Low	74.40	3.39	15

Table 1 showed that the average value of scientific literacy following the inquiry learning model with high achievement motivation (I - BT) is 84.52 higher than the average value of scientific literacy of students following the STAD type Cooperative learning model with high achievement motivation (M - BT) of 79.78. The average value of scientific literacy of students with the low motivation inquiry learning model (I - BR) of 77.45 is higher than the average value of scientific literacy of students with the STAD type cooperative learning model with low achievement motivation (S - BR) of 74.40. From the data in Table 1 above, it can be concluded that the average value of student literacy with the inquiry learning model of 80.98 is higher than the average scientific literacy of students following the STAD type cooperative learning model of 77.09. This shows that to improve student scientific literacy, the inquiry model is a very appropriate learning model because this model requires student activities to conduct investigations in accordance with the true meaning of inquiry.

To assess the impact of the learning model and achievement motivation on students' scientific literacy, we conducted a two-way ANOVA using SPSS version 26. This statistical test was chosen because it allows us to examine the influence of two independent variables (the learning model and achievement motivation) on a dependent variable (scientific literacy), as well as to explore any potential interaction between these variables. The two-way ANOVA is particularly useful in this study because it helps us determine not only if each independent variable has a significant main effect on scientific literacy but also whether their combined effect (interaction) is significant.

The results of the two-way ANOVA, presented in Table 2, show that the main effects for both the learning model and achievement motivation were statistically significant, as indicated by the p-values of 0.000 for both factors. This means that both the type of learning model and the level of achievement motivation independently influence students' scientific literacy. Specifically:

- **Learning Model**: The p-value for the learning model (p = 0.000) indicates that the type of learning model used (Inquiry vs. STAD Cooperative) has a significant impact on students' scientific literacy scores. This supports the hypothesis that the Inquiry Learning Model leads to better outcomes in scientific literacy compared to the STAD Cooperative Learning Model.
- **Achievement Motivation**: The p-value for achievement motivation (p = 0.000) confirms that students

with higher achievement motivation tend to perform better on scientific literacy tests, supporting the idea that motivation plays a crucial role in learning outcomes.

However, the interaction effect between the learning model and achievement motivation was not significant (p = 0.230). This suggests that the effectiveness of the learning model does not depend on the students' level of achievement motivation. In other words, while both factors independently affect scientific literacy, they do not combine to have a stronger or different effect depending on the motivation level of students. These findings provide useful insights into how different teaching methods can improve student learning outcomes in scientific literacy, and how student motivation interacts with these methods. The absence of a significant interaction effect indicates that the influence of the learning model on students' scientific literacy remains relatively consistent, regardless of whether students possess high or low achievement motivation. This implies that well-designed instructional strategies can yield beneficial outcomes across diverse motivational profiles, making them broadly applicable in varied classroom settings. It also highlights that educators can implement effective pedagogical models without necessarily tailoring them to different levels of student motivation, which simplifies instructional planning.

Despite the non-significant interaction, the strong and statistically significant main effects of both the learning model and achievement motivation emphasize their independent roles in shaping educational outcomes. Educators should therefore not interpret the lack of interaction as a reason to overlook motivation. Instead, they should continue to nurture intrinsic and extrinsic motivation through supportive classroom environments, goal-setting strategies, and relevant content that resonates with students' interests and future aspirations. From a policy and curriculum development standpoint, these results reinforce the value of investing in high-quality instructional design and motivation-enhancing programs. For instance, integrating inquiry-based or problem-based learning models can stimulate critical thinking and conceptual understanding, while structured motivational interventions can elevate students' engagement and persistence in learning. Future research may explore whether certain subgroups or contextual variables such as socio-economic status, prior academic background, or teaching experience might moderate the interaction between learning models and motivation, thereby uncovering more nuanced patterns. Ultimately, the findings underscore the importance of addressing both cognitive and affective domains in education to achieve comprehensive improvements in scientific literacy.

Table 2. Two-Way Analysis of Variance Results

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	445.771[a]	3	481.924	39.969	0.000
Intercept	617966.514	1	617966.514	51251.681	0.000
Model	74.836	1	374.836	1.087	0.000
Motivation	959.969	1	959.969	9.616	0.000
Model * Motivation	7.586	1	17.586	0.458	0.230
Error	446.899	120	12.057		
Total	**03709.000**	**124**			
Corrected Total	**892.669**	**123**			

[a] *R Squared = 0.500 (Adjusted R Squared = 0.487)*

The results of the hypothesis test presented in Table 2 indicate the following findings Students who participated in the Inquiry Learning Model achieved an average scientific literacy score of 80.98, whereas students who followed the STAD Cooperative Learning Model had an average score of 77.09. ANOVA revealed that the null hypothesis (Ho) was rejected, and the alternative hypothesis (H1), which stated that there was a significant difference in scientific literacy between the two groups, was accepted, with a significance value (Sig.) of 0.000, which is less than 0.05. There is a significant difference in scientific literacy based on students' achievement motivation, as indicated by the Sig. value of 0.000, which is less than 0.05 (H1 accepted). There is no significant interaction between the learning model and achievement motivation on students' scientific literacy, as shown by the Sig. value of 0.230, which is greater than 0.05.

The absence of interaction between learning models and achievement motivation towards scientific literacy is clearly seen in Figure 1.

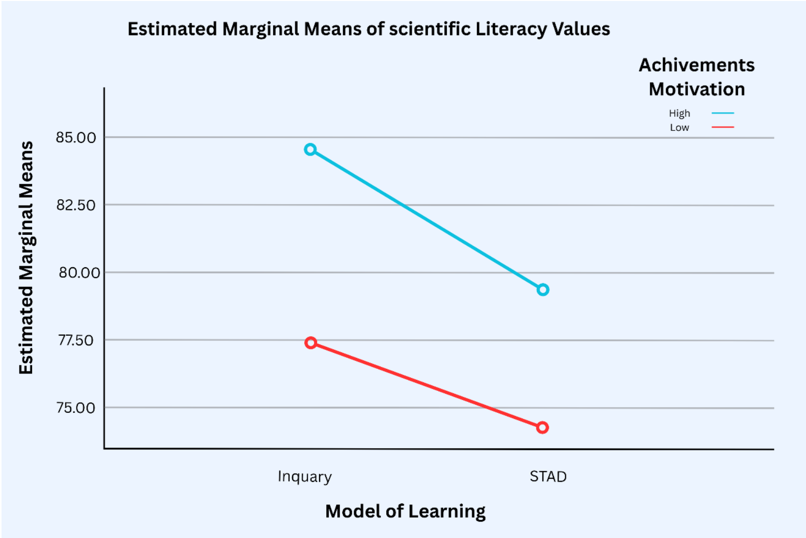

Figure 1. Interaction Between Learning Models and Achievement Motivation on Science Literacy

Another result found in this study is that there is a significant interaction between the learning model and achievement motivation on scientific literacy in students. Interaction means the work or influence of an independent variable on the dependent variable, depending on the level of other independent variables [49]. Its influence on students' scientific literacy, the learning model variable is very dependent on the achievement motivation variable in producing students' scientific literacy results. In other words, the influence of the learning model on scientific literacy is very dependent on the level of students' achievement motivation. For groups of students who have low achievement motivation, they tend to view the STAD type cooperative learning model as not being felt as a burden because students can only be discussion participants without many opinions and ideas, because students who excel will be responsible for their group because individual values are greatly influenced by group values. While in the Inquiry learning model, students freely discuss problems in everyday life in their groups [50]. Students seek more information, put forward initial concepts and connect with new challenging conditions. The role of the lecturer is as a facilitator, if asked for an explanation, the lecturer provides an initial description and then the students will work again to solve problems about the material being discussed.

4. MANAGERIAL IMPLICATION

Based on the findings of this study, several managerial implications are proposed for education administrators, policymakers, and practitioners aiming to enhance students' scientific literacy effectively:

4.1. Development and Implementation of Appropriate Learning Models

Educational management in higher education institutions should actively adopt and implement the Inquiry Learning Model as the primary teaching method, especially for students with low achievement motivation. This model has been proven more effective in improving scientific literacy compared to the STAD Cooperative Learning Model. Support for teacher training and capacity building to effectively apply the Inquiry Learning approach is essential.

4.2. Assessment and Enhancement of Student Motivation

Educational leaders are advised to regularly assess students' achievement motivation, which is a crucial factor influencing scientific literacy outcomes. Implementing motivation-boosting programs such as coaching, mentoring, and extracurricular activities can foster higher academic engagement and performance.

4.3. Provision of Supportive Facilities and Resources

School and university management should invest in and provide adequate facilities that support inquiry-based and cooperative learning environments. This includes well-equipped laboratories, interactive learning media, and digital technologies that enrich student learning experiences and engagement.

4.4. Flexible and Adaptive Curriculum Development

Curricula should be designed to be flexible and accommodate the balanced application of inquiry and cooperative learning models, tailored to student characteristics and class conditions. Academic management should facilitate periodic curriculum adjustments based on learning effectiveness evaluations and student needs.

4.5. Continuous Professional Development for Educators

Institutions must provide ongoing professional development programs focused on enhancing educators' skills in effectively implementing Inquiry Learning and STAD Cooperative Learning. Consistent application of these methods is vital to achieve high-quality educational outcomes.

4.6. Integration of Innovative Learning Models into National Education Standards

At the policy level, educational authorities should encourage the integration of innovative teaching models into national education standards to ensure widespread and systematic adoption. This will support the improvement of scientific literacy nationwide and contribute to achieving Sustainable Development Goal 4 (Quality Education).

5. CONCLUSION

This study found a significant difference in scientific literacy between students who followed the Inquiry Learning Model and those who followed the STAD Cooperative Learning Model, with the Inquiry Learning Model yielding higher results. Furthermore, the findings highlighted a strong interaction between achievement motivation and scientific literacy. Students exhibited higher literacy levels when motivated, especially in the Inquiry Learning group. While no significant difference in scientific literacy was observed between the two models for students with high achievement motivation, the Inquiry Learning Model proved to be more effective for students with low motivation. These results suggest that the Inquiry Learning Model is especially beneficial in enhancing scientific literacy among students with lower levels of achievement motivation.

Based on these findings, it is recommended that educators consider measuring students' achievement motivation before selecting an appropriate learning model. For students with high motivation, both the Inquiry and STAD models can be used effectively, but for students with low motivation, the Inquiry Learning Model should be prioritized to maximize improvements in scientific literacy. These recommendations aim to optimize the educational process and better align teaching methods with student motivation levels, ultimately contributing to enhanced student outcomes in science education. If the class has high motivation, the Inquiry Learning Model and the STAD Cooperative Learning Model can be used as alternatives, whereas if the class has low motivation, the Inquiry Learning Model should be the primary choice.

In addition to these considerations, educators, school administrators, and policymakers should take several managerial steps to effectively implement these learning models. Firstly, regular professional development programs should be organized for teachers to help them master both the Inquiry Learning Model and STAD Cooperative Learning techniques. This will enhance their ability to apply these models effectively in the classroom and boost students' science literacy. Furthermore, school administrators should consider adapting the curriculum to integrate these learning models, particularly for science subjects, to ensure alignment with modern, student-centered learning approaches. Additionally, schools should invest in necessary classroom resources, such as science kits, digital tools, and other materials that promote hands-on, exploratory learning. These resources will support both the inquiry learning model and STAD cooperative activities, fostering greater student engagement. Finally, policymakers should incorporate these innovative teaching models into national education standards for science education, ensuring their widespread adoption and consistent improvement in scientific literacy across educational institutions. By focusing on critical thinking, collaboration, and inquiry, these models contribute to the achievement of SDG 4 (Quality Education), preparing students for a competitive and rapidly changing world.

6. DECLARATIONS

6.1. About Authors

Muktar Bahruddin Panjaitan (MB) https://orcid.org/0000-0002-9524-5080
Asister Fernando Siagian (AS) https://orcid.org/0000-0002-4672-8553

Loso Judijanto (LJ) https://orcid.org/0009-0007-7766-0647
Mufarizuddin Mufarizuddin (MM) https://orcid.org/0000-0001-8982-8485
Herman Herman (HH) https://orcid.org/0000-0001-6818-5142
Nanda Saputra (NS) https://orcid.org/0000-0003-1181-3931
Zokir Mamadiyarov (ZM) https://orcid.org/0000-0002-1508-488X

6.2. Author Contributions

Conceptualization: MB; Methodology: AS; Software: LJ; Validation: MM and HH; Formal Analysis: NS and ZM; Investigation: MB; Resources: AS; Data Curation: LJ; Writing Original Draft Preparation: MM and HH; Writing Review and Editing: NS and ZM; Visualization: HH; All authors, MB, AS, LJ, MM, HH, NS and ZM have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] B. I. Ansari, J. Junaidi, S. Maulina, H. Herman, I. Kamaruddin, A. Rahman, and N. Saputra, "Blended-learning training and evaluation: A qualitative study," *Journal of Intercultural Communication*, vol. 23, no. 4, pp. 155–164, 2023.
[2] M. Frydenberg and D. Andone, *Learning for 21st Century Skills*, 2021.
[3] M. I. Adam, Y. Hanafi, and F. D. Sagita, "Teaching at the right level approach: Implementation guide inquiry & cooperative learning with feedback on the learning outcomes of students," in *Proceeding International Conference on Religion, Science and Education*, vol. 4, 2025, pp. 519–526.
[4] N. Purba, R. Purba, M. W. Setiyadi, C. P. Ate, R. Razali, N. Saputra, and H. Herman, "Analyzing the impact of digital information communication technologies (dict) on literacy development in third grade primary school: A case study on education," *Journal of Information Systems Engineering and Management*, vol. 10, no. 4s, pp. 345–352, 2025.
[5] A. Meria *et al.*, "The influence of learning models on scientific literacy in 21st century education," *Journal of Educational Research*, vol. 10, no. 2, pp. 123–135, 2025.
[6] A. Rizky, R. W. Nugroho, W. Sejati, O. Sy *et al.*, "Optimizing blockchain digital signature security in driving innovation and sustainable infrastructure," *Blockchain Frontier Technology*, vol. 4, no. 2, pp. 183–192, 2025.
[7] D. Ramdani, H. Susilo *et al.*, "The effectiveness of collaborative learning on critical thinking, creative thinking, and metacognitive skill ability: Meta-analysis on biological learning." *European Journal of Educational Research*, vol. 11, no. 3, pp. 1607–1628, 2022.
[8] D. I. Kusumaningtyas, N. Suprapto, and S. Suryanti, "Fostering science literacy: A comprehensive systematic review of learning models," *Multidisciplinary Reviews*, vol. 8, no. 9, pp. 2 025 292–2 025 292, 2025.
[9] N. M. Dah, M. S. A. M. Noor, M. Z. Kamarudin, and S. S. S. A. Azziz, "The impacts of open inquiry on students' learning in science: A systematic literature review," *Educational Research Review*, p. 100601, 2024.
[10] A. F. Siagian, M. Ibrahim, and Z. A. I. Supardi, "Creative-scientific decision-making skills learning model for training creative thinking skills and student decision making skills," *Nurture*, vol. 17, no. 1, pp. 10–17, 2023.

[11] N. Gultepe and Z. Kilic, “Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry,” *Journal of Environmental Science Education*, vol. 10, no. 1, p. 112, 2021.
[12] J. Holbrook and M. Rannikmae, “The meaning of scientific literacy,” *International Journal of Environmental Science Education*, vol. 4, no. 3, pp. 275–288, 2021.
[13] X. Liu, “Beyond science literacy: Science and the public,” *International Journal of Environmental and Science Education*, vol. 4, no. 3, pp. 301–311, 2021.
[14] OECD, *PISA 2022 Result (Colume I): The State of Learning and Equity in Education*. Paris: OECD Publishing, 2023.
[15] U. Rahardja *et al.*, “Analysis of renewable energy adoption in developing countries,” *Journal of Energy Studies*, vol. 15, no. 3, pp. 200–215, 2022.
[16] A. Schleicher, *PISA 2021 (Insights and Interpretations)*. Paris: OECD Publishing, 2021, vol. 5.
[17] A. F. Siagian and Z. A. I. Supardi, “Enhancing science education with digital tools: Impacts on student motivation and achievement,” *Journal of Educational Technology*, vol. 11, no. 3, pp. 45–58, 2022.
[18] J. Jones, E. Harris, Y. Febriansah, A. Adiwijaya, and I. N. Hikam, “Ai for sustainable development: Applications in natural resource management, agriculture, and waste management,” *International Transactions on Artificial Intelligence*, vol. 2, no. 2, pp. 143–149, 2024.
[19] F. Alfiah and N. R. Prastiwi, “Cyber security in smart grid technology: a systematic review,” *International Journal of Cyber and IT Service Management*, vol. 2, no. 1, pp. 48–54, 2022.
[20] D. Rychen and L. Salganik, *Key Competencies for a Successful Life and a Well-Functioning Society*. Cambridge, MA: Hogrefe & Huber, 2021.
[21] B. Öztürk, “The effect of cooperative learning models on learning outcomes: A second-order meta-analysis.” *Educational Policy Analysis and Strategic Research*, vol. 18, no. 3, pp. 273–296, 2023.
[22] H. Hamsinah, U. Rusilowati, and D. Sunarsi, “Analysis of lecturer competency and knowledge in technopreneurship development of student msmes in pts,” *Aptisi Transactions on Technopreneurship (ATT)*, vol. 6, no. 3, pp. 623–638, 2024.
[23] S. Wijaya *et al.*, “ilearning: The future of digital education in the 21st century,” *Journal of Digital Education*, vol. 18, no. 1, pp. 45–59, 2024.
[24] B. Trilling and C. Fadel, *21st Century Skills: Learning for Life in Our Times*. USA: Jossey-Bass, 2021.
[25] S. Setiawan, U. Rusilowati, A. Jaya, R. Wang *et al.*, “Transforming human resource practices in the digital age: A study on workforce resilience and innovation,” *Journal of Computer Science and Technology Application*, vol. 2, no. 1, pp. 84–92, 2025.
[26] C. Wenning, “Assessing nature-of-science literacy as one component of scientific literacy,” *Journal of Physics Teacher Education Online*, vol. 3, no. 4, pp. 3–14, 2021.
[27] H. Herman, A. M. Shara, T. F. Silalahi, S. Sherly, and J. Julyanthry, “Teachers’ attitude towards minimum competency assessment at sultan agung senior high school in pematangsiantar, indonesia,” *Journal of Curriculum and Teaching*, vol. 11, no. 2, pp. 01–14, 2022.
[28] J. Holbrook and M. Rannikmae, “Investigating science literacy as a component of education for sustainability,” *Science Education Research Journal*, vol. 7, no. 4, pp. 125–137, 2022.
[29] M. Frydenberg and D. Andone, “21st century skills in higher education: Bridging theory and practice,” *Higher Education Review*, vol. 14, no. 2, pp. 89–105, 2022.
[30] B. I. Ansari and A. Rahman, “Integrating technology and pedagogy in stem education: Best practices and challenges,” *STEM Education Journal*, vol. 22, no. 2, pp. 152–168, 2021.
[31] J. Junaidi and S. Maulina, “Assessing the impact of blended learning in science education: A case study,” *Educational Technology Review*, vol. 9, no. 3, pp. 233–245, 2021.
[32] A. R. Aditama, “Gamification in education: A study on engaging students through digital tools,” *Journal of Educational Psychology*, vol. 20, no. 1, pp. 76–83, 2022.
[33] M. W. Setiyadi and R. Razali, “The role of digital literacy in enhancing students’ learning experience in a post-covid world,” *Journal of Digital Education*, vol. 6, no. 2, pp. 112–120, 2022.
[34] A. Suleiman and A. Hannan, “The future of education in the digital era: Challenges and opportunities,” *Global Education Review*, vol. 5, no. 1, pp. 45–57, 2022.
[35] A. Kanivia, H. Hilda, A. Adiwijaya, M. F. Fazri, S. Maulana, and M. Hardini, “The impact of information technology support on the use of e-learning systems at university,” *International Journal of Cyber and IT Service Management*, vol. 4, no. 2, pp. 122–132, 2024.

[36] H. Hamna and M. K. U. BK, “Science literacy in elementary schools: A comparative study of flipped learning and hybrid learning models,” *Profesi Pendidikan Dasar*, vol. 9, no. 2, pp. 132–147, 2022.
[37] H. Nenti, P. Prasetyorini, and S. Eka, “Learning science with group investigation and guided inquiry to increase biological literacy in coordination system materials of class science xi students,” *Journal of Science Education and Practice*, vol. 5, no. 1, pp. 43–53, 2022.
[38] U. Rahardja *et al.*, “Technological innovations in education: A shift toward digital learning platforms,” *Journal of Educational Technology*, vol. 12, no. 2, pp. 105–120, 2023.
[39] D. A. Kurniawan, W. Sukarni, R. Hoyi *et al.*, “Assessing students’ attitudes towards physics through the application of inquiry and jigsaw cooperative learning models in high schools.” *International Journal of Instruction*, vol. 14, no. 4, pp. 439–450, 2021.
[40] A. A. Zainuddin, R. M. Nor, D. Handayani, M. I. M. Tamrin, K. Subramaniam, and S. F. N. Sadikan, “Smart attendance in classroom (cobot): Iot and facial recognition for educational and entrepreneurial impact,” *Aptisi Transactions on Technopreneurship (ATT)*, vol. 6, no. 3, pp. 608–622, 2024.
[41] R. Setiawan, D. Mardapi, and U. B. Karyanto, “European journal of educational research,” *European Journal of Educational Research*, vol. 9, no. 2, pp. 611–627, 2025.
[42] C.-M. Chen, M.-C. Li, and Y.-T. Chen, “The effects of web-based inquiry learning mode with the support of collaborative digital reading annotation system on information literacy instruction,” *Computers & Education*, vol. 179, p. 104428, 2022.
[43] T. Ramadhan, W. N. Wahid, H. Nusantoro, A. Rifki *et al.*, “New authoritative changes with blockchain an emphasis production network,” *Blockchain Frontier Technology*, vol. 2, no. 1, pp. 24–35, 2022.
[44] S. Setiawaty, I. Lukman, R. Imanda, S. Sudirman, and R. Rauzatuzzikrina, “Integrating of mobile augmented reality applications through inquiry learning to improve students’ science process skills and mastery of science concept,” *Jurnal Pendidikan IPA Indonesia*, vol. 13, no. 1, 2024.
[45] R. A. Bimantoro, “Inquiry learning model to improve critical thinking skills of high school students,” in *Prosiding Seminar Nasional Mahasiswa Matematika Unnes*, 2025, pp. 335–345.
[46] M. Usman, I. N. S. Degeng, S. Utaya, and D. Kuswandi, “The influence of jigsaw learning model and discovery learning on learning discipline and learning outcomes.” *Pegem Journal of Education and Instruction*, vol. 12, no. 2, pp. 166–178, 2022.
[47] B. Rawat, A. S. Bist, D. Supriyanti, V. Elmanda, and S. N. Sari, “Ai and nanotechnology for healthcare: A survey,” *Aptisi Transactions on Management (ATM)*, vol. 7, no. 1, pp. 86–91, 2023.
[48] A. D. Gustiana, R. Rahman, T. Hartati, and N. Supriatna, “Improving student’s reading interest through the jigsaw cooperative learning model in elementary school,” *Ta dib Jurnal Pendidikan Islam*, vol. 12, no. 1, pp. 181–200, 2023.
[49] Ministry of Education, Culture, Research, and Technology of Indonesia, “Online-based training and course program,” https://kursus.kemdikbud.go.id/, 2025, accessed: 2025-05-26.
[50] Statistics Indonesia, “Education statistics in indonesia 2024,” Government Publication, 2024. [Online]. Available: https://www.bps.go.id