RESEARCH ARTICLE

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An Extraordinary Duet: Integration of PjBL and STEM to Promote Student's Motivation, Scientific Literacy Skills, and Students Learning Outcomes

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ABSTRACT

This study aimed to investigate the effect of the STEM-integrated PjBL learning model on students' motivation, scientific literacy skills, and learning achievement. The study used a non-equivalent control group design with a population of eleventh-grade high school Islam Athirah II Makassar students. Science Class 1 and Science Class 2 were included in the sample. The research instruments consisted of a learning motivation questionnaire, a Test of Scientific Literacy Skill (TOSLS), and an achievement test consisting of 20 multiple-choice questions. The Independent Sample t-test was used to assess the research data. The results indicated that the STEM-integrated PjBL learning model had a significant effect on students' learning motivation, scientific literacy skills, and learning outcomes, with a significance value of 0.00 (<0.05). According to these findings, the STEM-integrated PjBL learning model can be utilized to increase students' motivation, scientific literacy skills, and learning outcomes.

Keywords: Integrated PjBL, Learning Outcomes, Motivation, Scientific Literacy Skills, STEM.

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I. Introduction

Scientific literacy is critical for every human to grasp since it is inextricably linked to one's ability to comprehend the environment and the issues confronting society due to the advancement of science and technology, including social issues (Afriana & Fifriani, 2016; National Academies of Sciences, Engineering, and Medicine, 2016). Scientific literacy skills can serve as a springboard for someone to act by assessing the potential repercussions. Thus, scientific literacy has a broader impact on human life than only research and technological progress; it reflects the societal culture. In the context of education, scientific literacy skills are needed by students. Scientific literacy encompasses knowledge of science, scientific processes, the development of scientific attitudes, and students' comprehension of science, such that students not only understand the concept of science but also possess the ability to apply scientific abilities in solving various problems and making decisions based on scientific considerations (Azwar, 2012; OECD, 2015). Students are expected to be able to apply classroom knowledge in real-world situations, demonstrating sensitivity and concern for the surrounding environment.

Indonesia was one of the nations that participated in the 2018 Program for International Student Assessment (PISA) study, with the country ranking 74th out of 79 countries surveyed. Indonesia received a science score of 396, a math score of 379, and a reading score of 371 in the survey, all of which are much lower than the OECD average of 489 (OECD, 2019). Indonesia's PISA results have remained unchanged over the last 10–15 years. Compared to the 2015 PISA results, the scores in all three categories of reading, math, and science declined significantly. According to the survey, Indonesian students' scientific literacy skills are still insufficient and should be improved.

The low level of scientific literacy among students is assumed to be a result of the learning process failing to foster the growth of students' scientific literacy or failing to prepare students to handle problems requiring high-level thinking, such as PISA questions (The Ministry of National Education, 2011; Fatmawati, 2016). Students' scientific literacy is also determined by their attitude toward science, which is influenced by emotional elements such as their motivation and comfort with science, as well as their participation in science learning (Lin *et al.*, 2012).

Inadequate motivation for learning can lead to unsatisfactory learning outcomes (Wandi *et al.*, 2014). The findings of an analysis of the national biology exam taken by High School/Islamic High School students in 2019 demonstrate the students' unsatisfactory learning outcomes. According to the national exam, High School/Islamic High School students majoring in science were generally highly capable of solving problems at the cognitive level of understanding and application. However, it turns out that only approximately 40% of pupils can correctly answer the application-level test. According to this analysis, the learning process should be capable of encouraging students to apply classroom concepts to real-world or everyday life circumstances (The Ministry of Education and Culture, 2019).

Enhancing students' ability to apply learned concepts can be accomplished by incorporating scientific literacy into the learning process (Turiman, *et al*, 2012). One of the efforts is to increase students' capacity to apply scientific principles in developing their scientific work skills. The treatment in question is to include Project-Based Learning (PjBL) in the classroom for Science, Technology, Engineering, and Mathematics (STEM) education. STEM-based project-based learning is a type of project-based learning that incorporates STEM subjects, notably science, technology, engineering, and mathematics. STEM education benefits students by fostering their critical thinking and competencies necessary for success in the profession and in resolving everyday challenges (Topalska, 2021). STEM education teaches pupils to be creative, analytical, and critical thinkers (Nurtanto *et al.*, 2020).

STEM-integrated Project-Based Learning (PjBL) can create meaningful learning experiences, particularly in science. This instructional strategy develops students' scientific work skills through projects that include one or more other scientific disciplines, such as technology, engineering, or mathematics. Therefore, STEM-PjBL education provides learners with a genuine understanding of how science impacts their lives and how science works around them (Wijayanti & Fajriyah, 2018).

A study revealed that the application of the STEM-integrated PjBL could improve the scientific literacy skills of male and female students (Afriana *et al.*, 2016). Research by Furi *et al.* (2018) shows that the integration of STEM-PjBL into instruction can help learners enhance their cognitive and psychomotor abilities.

The objectives of this study were to (1) Evaluate the learning motivation, scientific literacy skills, and learning outcomes of eleventh graders following the implementation of the PjBL learning model; (2) Evaluate the learning motivation, scientific literacy skills, and learning outcomes of eleventh graders following the implementation of the STEM-integrated PjBL model; (3) Investigate the effect of the PjBL learning model on the learning motivation, scientific literacy skills, and learning outcomes of eleventh graders; and (4) Investigate the effect of the STEM-PjBL model on the learning motivation, scientific literacy skills, and learning outcomes of eleventh graders.

II. Literature Review

A. *Project-Based Learning (PjBL) Model*

Project Based Learning is an innovative learning approach that emphasizes contextual learning through complex activities. The focus of learning lies in the core concepts and principles of a discipline of study, involving students in problem-solving investigations and other meaningful task activities, providing opportunities for students to work autonomously to construct knowledge, and produce real products (Thomas *et al.*, 1999; Kamdi, 2007; Insyasiska *et al.*, 2017).

According to Tinker (1992); Colley (2008) and Insyasiska *et al.* Susilo (2017), project-based learning (PjBL) is associated with science-based learning, which is what scientists do. Students involved in the project as a whole will choose a topic, decide on an approach, conduct experiments, draw conclusions, and communicate the results of the project they are working on.

The steps of project-based learning that must be planned are as follows: 1) Ask essential questions; 1) Posing essential questions or important questions. The questions should be relevant to real-world problems that require in-depth examination; 2) Planning. Students should be involved in planning activities to propose solutions through project work; 3) Scheduling. Teachers need to direct students to make scheduling in project work; 4) Supervising. Teachers must oversee project implementation by agreed-upon stages and schedules; 5) Making an assessment. Assessment in project-based learning entails determining student mastery of learning themes, evaluating the learning process, student's attitudes and skills, evaluating products, and evaluating student performance in presenting products (Sani, 2015).

B. *STEM-Integrated Project Based Learning*

Project Based Learning (PjBL) is a learning model suggested by the 2013 Curriculum, whereas STEM is more focused on designing a grand plan (Capraro, Capraro, & Morgan, 2013; Afriana, Permanasari, & Fitriani, 2016). PjBL can be integrated with STEM education (Nurtanto *et al*, 2020). In contrast to STEM-integrated PjBL, PjBL learning comprises distinct phases. PjBL shares certain traits with STEM-integrated PjBL, however, STEM-PjBL places a greater emphasis on the design process. The design process is a methodical approach to problem-solving that results in well-defined outcomes. The STEM-integrated project-based learning syntax consists of five steps, namely reflection, research, discovery, application, and communication. Each step of learning in STEM education aims to achieve a specific process (Afriana *et al.*, 2016; Laboy-Rush, 2010). The syntax of the PjBL STEM model can be explained in Fig. 1.

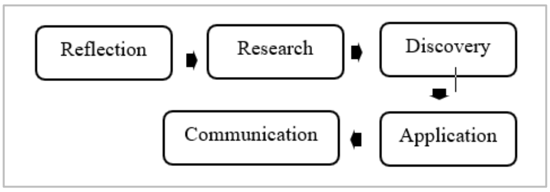

Fig. 1. STEM-Integrated PjBL Syntax.

III. Research Methods

The current study was carried out at high school Islam Athirah II Makassar, South Sulawesi, Indonesia. The population of this study contained the eleventh graders from the school, while the sample comprised students from Science Class 1 acting as the control group and students from Science Class 2 serving as the experimental group. The sample was selected using a random sampling technique. The STEM-integrated PjBL model was applied in the experimental class, while the project-based learning (PjBL) model was implemented in the control class. The pretest–posttest non-equivalent control group design used in this study is depicted in Table I.

TABLE I: Research Design

Group	*Pretest*	Treatment	*Posttest*	
Experimental	O_1	X_1	O_2	O_3
Control	O_4	X_2	O_5	O_6

Remarks:
- X_1: : The STEM-integrated PjBL model
- X_2: : The PjBL model
- O_1 : Pretest on the learning motivation, scientific literacy skills, and cognitive learning outcomes of the experimental group implementing the STEM-integrated PjBL model
- O_2 : learning outcomes of the experimental group implementing the STEM-integrated PjBL model
- O_3 : Posttest on the affective and psychomotor learning outcomes of the experimental class implementing the STEM-integrated PjBL model
- O_4 : Pretest on the learning motivation, scientific literacy skills, and cognitive learning outcomes of the control group implementing the PjBL model
- O_5 : Posttest on the learning motivation, scientific literacy skills, and cognitive learning outcomes of the control group implementing the PjBL model
- O_6 : Posttest on the affective and psychomotor learning outcomes of the control class implementing the PjBL model

The instructional process was conducted remotely, primarily via the Google Meet platform. The instruments utilized were a questionnaire survey on student motivation in learning (ARSC), a 15-question Test of Scientific Literacy Skill (TOSLS) sheet adapted and developed from (Gormally *et al.*, 2013), and a validated achievement test consisting of 20 multiple-choice questions. The pretest was used to assess the student's initial abilities, while the posttest was used to assess the study's findings. Multiple choice questions were included on both the pretest and posttest. Both tests were administered via a Google form online (on the network).

Data on the student's learning motivation, scientific literacy skills, and learning outcomes were collected using Microsoft Excel by first finding the mean (average) score and standard deviation. Furthermore, five levels of mean score categorization were determined using the formula from (Azwar, 2012).

TABLE II: Category of Learning Motivation, Scientific Literacy, and Learning Outcomes of Students at high school Islam Athirah II Makassar

Category	Formula
Very poor	$X \leq M - 1.5$ SD
Poor	$M - 1.5$ SD $< X \leq M - 0.5$ SD
Fair	$M - 0.5$ SD $< X \leq M + 0.5$ SD
High	$M + 0.5$ SD $< X \leq M + 1.5$ SD
Very high	$M + 0.5$ SD $< X$

Remarks: M (mean); SD (standard deviation).

The effect of the STEM-integrated PjBL model was determined by calculating the normalized gain score obtained from the pretest and posttest data. The average normalized gain score was calculated using the SPSS program. The average gain normalization criteria (Table III) were used as a reference in the hypothesis testing referred to (Hake, 2007).

TABLE III: Normalized Gain Score Criteria

Range	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

Meanwhile, the effectiveness of the STEM-integrated PjBL model in improving students' learning motivation, scientific literacy skills and learning outcomes was examined through hypothesis testing using the independent sample t-test.

IV. Result

The results of the analysis on the effectiveness of the PjBL model in improving students' learning motivation, scientific literacy skills and cognitive, affective, and psychomotor learning outcomes PjBL were summarized in Table IV.

The results of the N-gain analysis to examine the effectiveness of the STEM-integrated PjBL in improving the learning motivation, scientific literacy skills and learning outcomes of the experimental and control groups can be seen in Table V.

A. *Hypothesis Testing*

Following the data normality and homogeneity tests, hypothesis testing was conducted. The hypothesis testing on students' learning motivation, scientific literacy skills, and learning outcomes were performed using the independent sample t-test. The output result showed a significance value (2-tailed)<0.05, hence H0 was rejected and H1 was accepted (Table VI). Thus, it was concluded that the STEM-Integrated PjBL had a significant effect on the learning motivation, scientific literacy skills and learning outcomes of the eleventh graders from high school Islam Athirah II Makassar.

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TABLE IV: DESCRIPTIVE STATISTICS OF PARTICIPANTS' PRETEST AND POSTTEST SCORES

		Descriptive Statistics					
		Number of Subjects	Mean	Modus	Lowest Score	Highest Score	Standard Deviation
Learning Motivation							
PjBL	Pretest	20	47.90	45.00	29.00	64.00	10.115
	Posttest	20	70.55	65.00	65.00	76.00	3.410
PjBL STEM	Pretest	20	50.75	58.00	30.00	65.00	11.327
	Posttest	20	81.70	85.00	73.00	90.00	5.232
Scientific Literacy Skills							
PjBL	Pretest	20	50.60	40.00	27.00	70.00	14.166
	Posttest	20	78.35	77.00	67.00	87.00	5.422
PjBL STEM	Pretest	20	50.05	35.00	35.00	68.00	11.185
	Posttest	20	82.30	80.00	72.00	95.00	6.713
Cognitive Learning Outcomes							
PjBL	Pretest	20	53.80	40.00	36.00	72.00	11.998
	Posttest	20	78.80	76.00	64.00	92.00	8.811
PjBL STEM	Pretest	20	54.60	48.00	36.00	72.00	10.644
	Posttest	20	85.20	88.00	72.00	96.00	6.849
Affective Learning Outcomes							
PjBL	Posttest	20	85.10	80.00	83.00	90.00	3.386
PjBL STEM	Posttest	20	84.55	83.00	79.00	90.00	3.677
Psychomotor Learning Outcomes							
PjBL	Posttest	20	85.65	90.00	80.00	90.00	3.249
PjBL STEM	Posttest	20	85.92	83.00	79.00	92.00	4.159

TABLE V: N-GAIN SCORES FOLLOWING THE IMPLEMENTATION OF THE PJBL AND STEM-INTEGRATED PJBL MODELS IN THE EXPERIMENTAL AND CONTROL CLASSES

Indicator	N-Gain STEM-PjBL	Category PjBL	
Motivation	0.61	0.42	Medium
Scientific literacy skills	0.63	0.47	Medium
Learning Outcomes	0.65	0.51	Medium

TABLE VI: HYPOTHESIS TESTING OF THE EFFECT OF STEM-INTEGRATED PJBL ON THE LEARNING MOTIVATION, SCIENTIFIC LITERACY SKILLS, AND LEARNING OUTCOMES OF THE ELEVENTH GRADERS FROM HIGH SCHOOL ISLAM ATHIRAH II MAKASSAR

Variable	t-value	Df	Sig. (2-tailed)
Learning motivation	-4.597	38	0.000
Scientific Literacy	1.087	38	0.004
Learning Outcomes	2.015	38	0.001

V. DISCUSSION

The results of the descriptive analysis showed that the mean scores of learning motivation, scientific literacy skills, and learning outcomes of the eleventh graders at high school Islam Athirah II Makassar increased from low (pretest) to high (post-test) after the implementation of the PjBL learning model. However, the results of the N-Gain analysis indicated that the PjBL learning model was not particularly effective in enhancing learning motivation, scientific literacy skills, and student learning outcomes because the N-Gain score was in the medium range. This score could be related to the fact that the PjBL learning model has not been entirely able to boost students' learning motivation and learning outcomes. Other elements that can affect student motivation and learning outcomes are the learning environment, and online learning that does not allow face-to-face encounters between students and teachers, or between students and other students.

Overall, the results of these statistical analyses indicate that the PjBL learning model has the potential to affect students' attention to remain focused on learning and pique their interest in the learning material (Coordination System). Along with self-confidence, the PjBL learning model boosts students' enthusiasm for completing assigned tasks and assessments. Students are directly involved in their learning and interact with real-world conditions when they create projects about the coordination system's health. As a result, they obtain a meaningful learning experience and their motivation and engagement in learning rise appropriately.

Meanwhile, the results of the descriptive analysis of the mean pretest and posttest scores of learning motivation, scientific literacy skills, and learning outcomes of the research participants showed that the eleventh graders from the high school Islam Athirah II Makassar were able to increase their learning motivation, scientific literacy skills and their learning outcomes from low (pretest) to high (post-test) after the implementation of STEM-Integrated PJBL. Furthermore, the data analysis revealed that the experimental group's motivation for learning, scientific literacy skills, and learning outcomes was much higher than those of the control group (PjBL learning model). Although both groups achieved an average pretest score in the high range, their scores were not significantly different. This demonstrates that the two learning models are descended from the same learning model, however one of them has been updated to incorporate the STEM approach. Indeed, the STEM-integrated PjBL retains the syntax or stages of learning associated with project-based learning (PjBL). Additionally, the N-Gain analysis demonstrated that the STEM-integrated PjBL learning model was effective in increasing students' motivation, scientific literacy skills, and learning outcomes with an N-Gain score in the medium range.

Additionally, the independent sample t-test results indicate that the STEM integrated PjBL learning model affects student motivation, scientific literacy abilities, and learning outcomes. The mean scores attained by students in the STEM-integrated PjBL model class demonstrate this. In terms of motivation for learning, the STEM-integrated PjBL

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learning model has the potential to direct students' attention toward learning and to stimulate students' interest in the learning topic being presented (coordination system). Along with enhancing students' confidence, PjBL also increases students' enthusiasm for completing tasks and taking tests.

According to Afriana *et al.* (2016), both female and male students expressed satisfaction with the STEM-based PjBL learning approach deployed in the classroom. This is because STEM-based project-based learning encourages students to engage in meaningful learning activities that aid in their comprehension of a concept. Students are asked to explore and participate actively in the process of project creation in the STEM-integrated PjBL program (Ismayani, 2016).

The STEM-integrated PjBL model allows students to develop their abilities and make connections between the context of the material and activities in the classroom. A critical component of STEM-integrated PjBL is that students communicate their solutions with their peers, which helps students improve their communication skills (Thomas, 2002). As communication skills improve, motivation and comprehension of the topic improve as well. Students are allowed to tackle difficulties through the development of a project that utilizes their material knowledge. The results of the analysis on the effectiveness of STEM-integrated PjBL showed that students became more interested in learning (Bicer *et al.*, 2015).

The study conducted by Capraro *et al.* (2013) demonstrated that the STEM-integrated PJBL learning approach attracted and engaged students. This is because, during the STEM-Integrated PjBL learning process, students complete learning tasks autonomously, with the teacher guiding and directing students to identify and solve problems in Biology. STEM challenges and pushes students to develop critical thinking, analysis, and higher-order thinking skills through project-based learning.

Additionally, through the implementation of STEM-integrated PjBL, students learn the capacity to connect material principles to projects by the intended style or product design. Students can propose solutions to challenges related to the health of the human coordination system through design exercises that involve engineering abilities. In contrast to the PjBL learning model, STEM-PjBL projects incorporate engineering components. Earlier studies have demonstrated that using engineering abilities to design can enhance students' passion for learning (Tati *et al.*, 2017). According to Baran and Maskan (2010), the STEM-integrated PjBL approach has a positive effect on pupils.

The findings in this study reveal that STEM-integrated PjBL is effective in increasing students' learning motivation, scientific literacy skills, and learning achievement in coordination system materials because the learning model involves aspects of science, technology, engineering, and mathematics. The STEM-integrated PjBL model can be used as an alternative learning strategy that can be applied in the classroom to improve students' learning motivation, scientific literacy skills, and learning outcomes.

VI. Conclusion

Based on the data analysis and discussion, it was concluded that there was a significant difference between the experimental class and the control class after the implementation of the learning models. The experimental group performed better than the control group in terms of learning motivation, scientific literacy skills and learning outcomes. Therefore, it can be concluded that the STEM-integrated PjBL learning model affects the learning motivation, scientific literacy skills, and learning outcomes of eleventh graders in high school.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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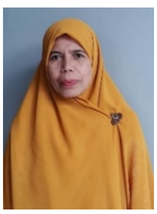
Dr. Sitti Saenab S.Pd, M.Pd was born in 1981 in Pangakajene, South Sulawesi. Indonesia. Started serving in the Department of Biology in 2009-2017 and in 2017 moved home based in the UNM Science education study program. Actively conducting research in the field of Biology and Science learning. Fields of research studies include learning biology and science to improve students' critical thinking, collaborative, and communication skills as well as increasing students' scientific literacy.

Prof. Dr. Drs. H. Abdul Hadis, M.Pd. born in 1963 in Sengkang, Wajo Regency, South Sulawesi, Indonesia. He has been a Lecturer at Makassar State University since 1990 in the Educational Administration Study Program, Earning the title of professor in 2008. Currently he is also a Muballiq/Islamic Lecturer at various mosques in Makassar City and in South Sulawesi, as Advisor-Builder of the City Jamiatul Khair Dakwah Institute Makassar in 2022, as an Entrepreneur for Lodging in Makassar City since 1993 and has been the Grand Imam of the Al Ikhlas Mosque in Makassar City since 2017 until now. In 2011 was Excellent Presenter in English at the International Conference at the Grand Clarion Hotel. Active in researching the field of student development studies.

Nurul Ilmi R.H S.Pd. was born in 2000 in Malang, East Java. Indonesia. Completed bachelor's degree Program in the Department of Biology FMIPA at Makassar State University in 2017 Currently serving as a high school biology teacher.



Dra Remiza was born in 1964 in Tanjung Bonai, Tanah Datar, West Sumatra. Indonesia. He completed his undergraduate education studies at IKIP Ujung Pandang in 1989. He started his career as a biology teacher at Athirah Islamic High School from 1999-2003 and at Athirah Islamic Middle School in 2003. Currently she is a biology teacher at Athirah Bukit Baruga Islamic High School until now.