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Project-Based and Flipped Learning in the Classroom: A Strategy for Enhancing Students' Scientific Literacy

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Abstract: Scientific literacy is a critical competency for people to take an essential role in science, technology, and social advancement. It is important to note that this competence is still a problem for most students worldwide. Therefore, this study analysed students' scientific literacy differences between a project-based learning flipped classroom (PjBL-FC) and a project-based learning (PjBL) class assisted by learning resources in wetlands environments. This quasi-experimental study used a non-equivalent control group design involving Class X Senior High School as the sample. The data were inferentially analysed by t-test. The results showed that the scientific literacy of students in the class that applied the PjBL-FC was better than those who applied only PjBL. Furthermore, all the indicators reach the high to very high category except the ability to propose a hypothesis, which is in the medium category. It was concluded that flipped classroom makes the PjBL take place more efficiently and effectively. Further studies can be carried out to determine how students use the learning materials, how teachers design the PjBL strategy in an online platform, their effect on scientific literacy, and how to combine PjBL with other approaches.

Keywords: *Environment-based learning resources, flipped classrooms, project-based learning, scientific literacy*

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Introduction

Scientific literacy (SL) is a person's ability to engage with science-related issues and ideas as a reflective citizen. Furthermore, it is defined operationally as the ability to use scientific knowledge and process to identify questions and draw evidence-based conclusions (Dani, 2009; Organisation for Economic Cooperation and Development [OECD], 2015; Rahayu, 2017). There are three skills involved: scientifically explaining phenomena (based on facts and ideas), evaluating and designing inquiry, and interpreting data and evidence (OECD, 2015).

Scientific literacy has become a part of global citizenship education (GCE), which is essential to equip students to understand issues and becomes literate citizens (Yusof et al., 2019). Therefore, students will be ready to take an essential role in science, technology, and social advancement. The science curriculum must contribute by providing a learning experience for students to face in the future. The content needs to be relevant to local and global developments; hence, students will practice appropriate decision-making (science-based social issues) (Yacoubian, 2018).

However, the achievement of scientific literacy still needs to improve among students in various countries involved in the PISA test. About 72% of the student's scientific literacy is at levels 1 to 2, 36% at 3, and only 1% at 4 (OECD, 2019). In this case, 60% of Indonesian students are still below level 2 of the total six (OECD, 2019). Most of them are just beginning to have the competence to be involved in reasoning about science and technology and related issues. They can only apply basic or everyday scientific knowledge and investigation in known contexts. Sukowati et al. (2017) reported that 10th graders of Senior High School (aged 14-15 years) showed an average scientific literacy test in the low category. Furthermore, Merta et al. (2020) found that 48% of Junior High School students have scientific literacy skills in the low to deficient category.

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The low level is closely related to how the learning process occurs in the classroom (Ardianto & Rubini, 2016). Science subjects such as biology, chemistry, and physics have defined scientific literacy as a goal that needs to be achieved during the learning process. The use of inappropriate strategies has resulted in scientific literacy not being appropriately trained. Therefore, students cannot relate their knowledge to natural phenomena (Rosana et al., 2020) or problems encountered in their daily lives.

Several studies reported the success of using problem-solving-based learning models in science learning. The application of guided inquiry (Merta et al., 2020; Prasetya et al., 2019) and the project-based learning (PjBL) model (Sholahuddin et al., 2021) significantly improved scientific literacy. Compared to other problem-solving-based strategies, PjBL has an advantage because the learning is done through solving real-life problems in the form of projects (Cörvers et al., 2016). Through the PjBL model, students can master concepts and develop problem-solving and social skills (Afriana et al., 2016; Mosier et al., 2016; Mutakinati et al., 2018; Tseng et al., 2013). However, the application of PjBL has a disadvantage in that it takes a longer time. Because students must understand the problems, design, and complete specific projects that are often impossible to do during class hours. Therefore, students need to be guided and supported effectively; emphasis should be given to effective time management and student self-management (Kokotsaki et al., 2016; Sholahuddin et al., 2021).

Several studies reported that the flipped classroom approach reduced the time needed for learning, and the learning process was efficient. This approach inverts the traditional classroom by introducing course concepts before class, allowing teachers to guide each student through active, practical, and innovative applications of the course principles (Academy of Active Learning Arts and Sciences [AALAS], n.d.; Chen et al., 2014). Students can independently study the learning materials using teachers' guidance in modules, worksheets, videos, or other forms before classroom learning. The most frequently reported advantage of the flipped classroom is the improvement of student performance (Akçayır & Akçayır, 2018; Jdaitawi, 2019; Knutas et al., 2016; Strelan et al., 2020; Wei et al., 2020). When they learn in class, the teachers focus on facilitating group work or important activities to explore and complete projects. Therefore, the lesson time is more effective and increases creativity and performance compared to the traditional approach (Al-Zahrani, 2015; Olakanmi, 2016). It also increases motivation and cognitive load to support learning goals (Abeysekera & Dawson, 2015). The flipped classroom was proven successful in increasing students' enthusiasm for learning, providing more opportunities for peer interaction, self-preparing before the class meeting, and obtaining immediate instructor feedback (Zainuddin, 2017).

Based on the above reasons, this study combined PjBL and flipped classrooms to streamline the time for implementing learning and still benefit the PjBL's advantages in fostering scientific literacy, social skills, and self-directed learning through authentic project completion. One of the best practices was reported by Chua and Islam (2021), but it was conducted on a second-year engineering student. Also, PjBL-FC increased fundamental formative knowledge, problem-solving abilities, and artefacts (design skills and creativity) performance compared to traditional PjBL. At the secondary school level, the flipped classroom was more beneficial to students at the middle mathematics level compared to those at high or low levels (Wei et al., 2020).

The approach has been carried out in higher education, including postgraduate students, some at the secondary level and very little at the elementary school (Cheng et al., 2019; Goedhart et al., 2019; Strelan et al., 2020). The application of flipped classrooms in some undergraduate lectures does not show any difference in learning outcomes compared to traditional classes that apply the method (Cabi, 2018; Gillette et al., 2018). This fact is presumed due to the development level of student learning autonomy. Also, the flipped classroom provides structured, active, and problem-solving learning and requires students' autonomy, such as PjBL. Even though it has been implemented in various fields (Cheng et al., 2019; Strelan et al., 2020), the application combined with PjBL at lower educational levels is still a challenge. Most studies related to the implementation were carried out as a single strategy, and some were combined with others, such as PjBL. It also requires adjusting to the lower level of students' learning autonomy due to their personality development.

This study utilized resources from the environment to provide more meaningful learning. Using resources from the students' environment will help them construct the knowledge and experience they already have with the new concepts being taught (Kristyowati & Purwanto, 2019; Sholahuddin, 2015). The social environment or local potential is proven to indefinitely improve the knowledge of science materials (Hadi et al., 2020). A wetlands area comprises a river environment, swamp, freshwater, brackish water, or salt, including areas of marine water with a depth that at low tide does not exceed six meters that are always flooded in the year (Adeleke, 2019; Wetlands International, n.d.).

The PjBL strategy was widely applied separately from the flipped classroom (FC) approach. The previous studies above showed that implementing PjBL has successfully increased student involvement in learning, knowledge, and various skills, including problem-solving skills and scientific literacy. However, the learning process takes a long time. At the same time, the flipped classroom approach was proven to streamline students' learning time because they have started learning before they take part in the classroom learning. During the classroom meeting they focus more on deepening the learning material and solving the problems. Therefore, the combination of PjBL with a flipped classroom is thought to have an impact on the achievement of students' scientific literacy more efficiently. Meanwhile, the use of learning resources that are close to the student's environment provides motivating and meaningful learning for students of the secondary school level. Based on the facts, this study collaborates the project-based learning flipped classroom (PjBL-FC) approach in learning electrolyte and non-electrolyte concepts. Furthermore, it used the wetland's environment to improve scientific literacy efficiently. This learning source is fruits grown in wetlands, peat soils, and water from wetlands relating to electrolyte and non-electrolyte solutions.

This study aims to analyse scientific literacy differences between classes using the PjBL-FC and the PjBL model supported by the wetlands environment resources. This study will theoretically contribute to the advantages of combining PjBL and flipped classrooms in facilitating knowledge construction through chemistry learning and its impact on increasing scientific literacy. This study also helps teachers to design an effective and efficient chemistry learning through PjBL and Flipped Classroom strategies.

Methodology

Study Design

This study used a quasi-experimental method with a pretest-posttest non-equivalent control group design (Fraenkel et al., 2012). Furthermore, it was carried out in the even semester of the 2019/2020 academic year.

Sample and Data Collection

The participants were selected using the cluster random sampling technique. The research samples were grade 10 of mathematics and science specialization class (MSSC) 2 (the experimental class), and *the MSSC* 1 (as control class) of the Senior High Schools in Banjarmasin South Kalimantan, Indonesia. Each class sample consists of 36 students. The experimental class consisted of 10 male and 26 female students, while the control class consisted of 9 male and 27 female students. The experimental class applied the PjBL-FC, while the control used only the PjBL with the same learning resources. Both students in the experimental and control classes have an average age between 13-14 years. The placement of students in all classes of participating schools was carried out randomly so that each class was a mixture of students with various academic abilities and socioeconomic statuses. However, most students have the moderate academic ability and come from economically well-off families. They already have experience participating in individual and collaborative learning and conducting discussions and presentations in class. In addition, they have studied several chemical concepts in the previous semester, such as the scientific method and the nature of chemistry, atomic models, the periodic table and atomic properties, chemical bonds, valence shell electron pair repulsion theory, and the interaction of ions, atoms, and molecules and their relationship to the nature of matter.

The class that used the PjBL-FC carried out learning in 2 stages, namely pre-class (at home or outer class) and in-class (face-to-face activities), while the control only used face-to-face activities as a usual learning process. The pre-class activities were the first stage in a flipped classroom where students read the learning materials and related videos before entering class. Besides, they were given project assignments related to the learning material before the class. Teachers require students to ask at least one question during learning to ascertain whether they have studied the material. This design was applied to the chemistry learning of electrolytes and non-electrolytes over four meetings in 4 weeks. The stages of the PjBL-FC are presented in Table 1.

Table 1. The Stages of the PjBL-FC (Arends, 2012; Brundiers & Wiek, 2013)

Stages	The flipped classroom activities
Project determination *(Orienting)*	Pre-class: The teacher gives the learning materials to the students before entering the class. Students learn independently outside the class or at home and look for more related literature to have prior knowledge before the next class. Class: Students determine project themes/topics based on the assignments given by teachers. This stage train students' ability to process and correct predictions.
The project design *(Framing)*	Pre-class: Students read the learning materials and listen to related videos. Furthermore, they design the steps of project activities from the beginning to the end and determine the schedule. Class: Students establish their project design, steps, and schedule by discussing it in their groups. Students complete the project design in class, including estimated schedules, which shortens the time spent. Students describe the steps to be carried out in a detailed, complete, and realistic manner; hence, skills such as identifying, using, and producing explanatory and representation models can be improved.

Table 1. Continued

Stages	The flipped classroom activities
Project completion *(Doing)*	Pre-class: Students prepare whatever they need to implement their projects. Class: Each participant work on the project following their design. The design and schedule that have been made are then carried out at the project completion stage. A project monitoring checklist is provided on the student's worksheet, which has to be filled out. It consists of 3 parts, namely preparation, implementation, and publication. The preparation stage contains a list of implementation plans. This stage allows students to distribute tasks evenly to group members according to the planned design and schedule. The publication stage aims to help students prepare everything needed when delivering the results. At the completion stage, students are trained to identify questions or problems during the implementation and provide solutions. They also practice connecting facts or objects in the environment with scientific knowledge about electrolytes and non-electrolytes. This learning process will foster scientific literacy skills in explaining the potential implications of scientific knowledge on society.
Presentation of Work *(Presenting)*	Pre-class: Students prepare the tools they need to present their projects. Class: Students present/publish project results to their peers and teachers. Other students can provide evaluations in the form of responses to questions, suggestions, or improvements. This stage fosters scientific literacy skills in analysing, interpreting, and drawing conclusions based on the data.
Evaluating the process and work *(Evaluating)*	Pre-class: Learning materials are given to the students before entering class. Class: Students and teachers reflect on the activities and the completed project. Students and teachers evaluate the process and the results presented by each group. Teachers provide clarification and reinforcement; hence, students can determine whether the work is correct. This stage fosters scientific literacy skills to identify assumptions, evidence, and reasons for certain scientific statements.

Data collection was carried out using an essay test or open-ended question to measure the students' scientific literacy. The test instrument consists of 10 items of essay form arranged based on the PISA indicators with the qualifications, as shown in Table 2. The indicators of scientific literacy (OECD, 2015) include (a) Explaining scientific phenomena. This indicator involves repeating and applying the appropriate knowledge, explaining the potential implications for society and identifying, using, and generalizing representation. (b) Evaluating and designing scientific research. This indicator involves offering explanatory hypotheses, identifying questions explored in a given scientific study, proposing how to explore the questions, and evaluating how to explore the questions. (c) Interpreting data and evidence. This indicator involves analysing and interpreting the data and drawing appropriate conclusions, changing the data from one representation to another, and identifying assumptions, evidence, and reasons for related scientific statements.

Table 2. The Qualification of Scientific Literacy Test Instruments

Parameters	Method	Index / Coefficient	Category	Reference
Content Validity	Aiken's V validity coefficient	.95-1.00	Valid	Nair et al., 2017
Reliability	Cronbach's Alpha	.91	High	Arikunto, 2015
Difficulty index	Difficulty index	.56	Average	Arikunto, 2015
Discrimination index	Discrimination index	.45	Good.	Arikunto, 2015

Analysing of Data

The data were first subjected to prerequisite tests of normality (*Liliefors*, L_o) and homogeneity (*F test* at α = .05) before being analysed with the unpaired *t-test*. Furthermore, the data were analysed for their N-gains to determine the increase in scientific literacy before and after learning. The *N-gain* classifications score are $<g>$ = .7 to 1.0 (Good), .3 ≤ $<g>$ ≤ .7 (Moderate) and < .3 (Low) (Hake, 2002). The categorizations of scientific literacy are as follows: 0-20 = very low, 21-40 = low, 41-60 = moderate, 61-80 = high, and 81-100 = very high.

Findings/Results

Scientific Literacy

Based on the application of the PjBL-FC and PjBL models, the scores of Students' Scientific Literacy Skills in the experimental and control classes are presented in Table 3.

Table 3. The Score of Students' Scientific Literacy Skills

No.	Skills	Experimental Class		Control Class	
		Pre-test PjBL-FC	Post-test PjBL-FC	Pre-test PjBL	Post-test PjBL
1	Explaining scientific phenomena	36.11	89.81	29.32	78.09
2	Evaluating and designing a scientific study	22.92	72.92	22.22	65.97
3	Interpret data and evidence	16.05	84.73	14.50	72.84
	Average	24.76	81.11	22.04	71.67
	N-gain	.74		.62	

Meanwhile, the achievement of SL in both classes based on the indicators is presented in Figure 1. Based on the data, all the measured indicators reached an average score of > 61 or were in a good category. The highest achievement indicator in the PjBL-FC and PjBL classes was repeating and applying the appropriate knowledge.

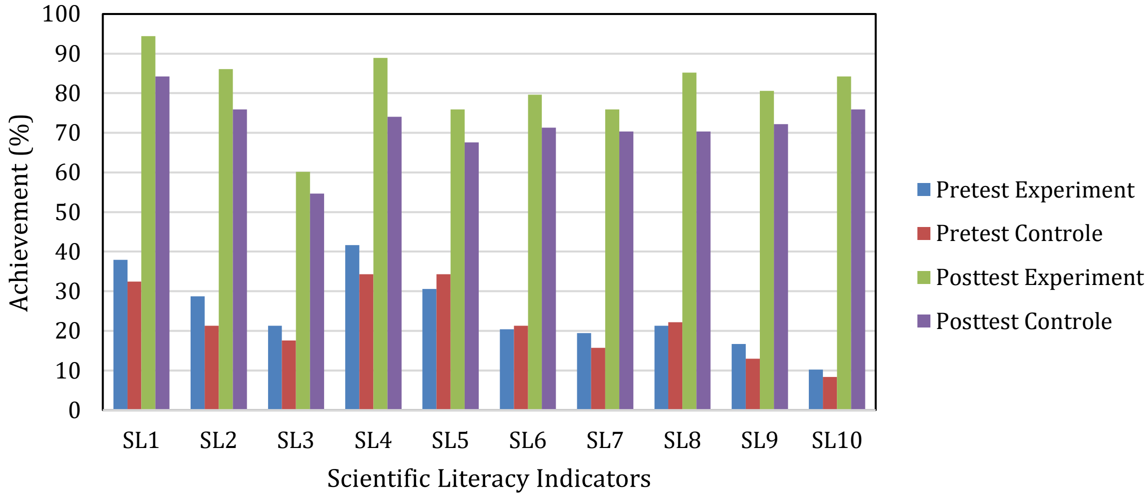

Figure 1. The Achievement of Scientific Literacy

Description:

SL1: Repeating and applying the appropriate knowledge

SL2: Explaining the potential implications of scientific knowledge for society

SL3: Offering a hypothetical explanation

SL4: Identifying, using, and generalizing the picture

SL5: Identifying questions explored in the given scientific study

SL6: Proposing how to explore the given questions scientifically

SL7: Evaluating how to explore the given questions scientifically

SL8: Analysing and interpreting the data and drawing appropriate conclusions

SL9: Changing the data from one representation to another

SL10: Identifying assumptions, evidence, and the reasons for scientific statements.

Normality Test

The summary of the normality test data in the experimental and control class is presented in Table 4. According to the results, the pre-test and post-test scientific literacy data distribution of students in the two classes are normally distributed.

Table 4. The Summary of Normality Test of Scientific Literacy Data

Results	Class	N	L_0	L_{table}	$L_{\alpha = .05}$	Conclusion
Pre-test	Experiment	36	.136	.148	$L_0 < L_{table}$	Normal
	control	36	.133	.148	$L_0 < L_{table}$	Normal
Post-test	experiment	36	.067	.148	$L_0 < L_{table}$	Normal
	Control	36	.084	.148	$L_0 < L_{table}$	Normal

Homogeneity test

The summary of the normality test data using the F test in the experimental and control class is presented in Table 5. According to the results, variants of students' scientific literacy data from two classes before and after being treated are the same.

Table 5. The Summary of Homogeneity Test of Scientific Literacy Data

Results for	ClassClass	df	SD^2	F_{count}	F_{table}	$F_{\alpha = .05}$	Conclusion
Pre-test	Experiment	35	249.13	1.33	1.76	$F_{count} < F_{table}$	Homogeneous
	Control	35	186.84				
Post-test	Experiment	35	57.13	.53	1.76	$F_{count} < F_{table}$	Homogeneous
	Control	35	108.26				

t-test

The summary of t-test data in the experimental and control class that was normal and homogeneous is presented in Table 6. According to the results, the scientific literacy of the experimental class was better than the control after following the learning process.

Table 6. The Summary of t-test of Scientific Literacy Data

Results	Class	df	$\bar{X}$	SD^2	t_{count}	t_{table}	$t_{\alpha = .05}$	Conclusion
Pre-test	Experiment	35	24.76	249.13	.78	1.99	$t_{count} < t_{table}$	Not significantly different
	Control		22.04	186.84				
Post-test	Experiment	35	81.11	57.13	4.41	1.99	$t_{count} > t_{table}$	Significantly different
	Control		71.67	108.26				

Discussion

Both participated classes in this study followed the same learning stages of PjBL (Table 1). The difference between them is the pre-class activities in the flipped classroom of the experimental class (PjBL-FC). Through the pre-class activities, students benefited from the initial exposure to the material because it gave them prior knowledge before the next class (Capaldi, 2017). Mandating students to ask questions makes them pay more attention and effort to understand the concept and project. In the control group, all the activities in each PjBL syntax were carried out in class. Meanwhile, the experimental class activities for determining projects, designing, and scheduling were carried out in the outer class or at home. When students meet in the next class, they focus on project completion activities.

The second stage of the PjBL-FC is a classroom activity. This strategy makes the learning time more efficient for completing project determination, design, and schedule preparation in the experimental class. This is because students have been allowed to determine the project and prepare the materials and worksheets at home. Furthermore, they bring their prior knowledge and design drafts into the classroom to be discussed in groups according to the learning stages. Students discuss and present arguments related to the design and its completion. Rahayu et al., 2020) stated that the discussion process and interaction among students in the learning process caused an increase in motivation to learn, leading to higher achievement. Students in both classes completed the two projects through PjBL-FC (Tabel 1) or PjBL steps. The first project was to design and test various fruits in the wetlands to replace batteries, such as "kuit" limes, papayas, and starfruit. The second involved designing a simple electrolyte test kit based on the first project results to test various solutions. Students bring various solutions from the wetlands and those found daily, such as soap, sugar, table salt, and vinegar, to be tested.

An example of a project design is a simple electrolyte test equipment for testing various solutions, as presented in Figure 2.

Tools	***Materials***
Big Battery 4 pieces	*Lime "kuit"*
Small Battery 2 pieces	*Papaya*
Cable	*Peat water*
Styrofoam	*Lime*
Scissor	*Sugar solution*
Cutter	*Salt solution*
Small lamp 3 watt	*Detergent*
Duct tape	*Vinegar*
Solution bottle	*Coconut water*
Sandpaper	*Starfruit*

Write down the working steps to make a circuit of electrolyte test equipment!
1. Take out a small battery paste and take the carbon electrode.
2. Arrange a large battery on the Styrofoam that has been prepared as a holder
3. Connect the cable with the positive pole and the other wire with the negative.
4. Connect the wires to the lamp, and the ends are connected to the carbon electrode.
5. The end of the cable that is connected to the other battery is also connected to the carbon electrode
6. Pour each solution into the glass
7. Dip the two electrodes that have been arranged in the solution
8. Observing the light on the test equipment and the bubbles formed on the electrodes
9. Repeat the above steps for all the different solutions

Figure 2. The Project Design for Making a Simple Electrolyte Test Device That Will Be Tested on Various Types of Solutions

The design and schedule that have been made are then carried out at the project completion stage (Figure 3).

Figure 3. The Project Completion

Table 1 shows the scientific literacy of the experimental class is better than the control class. The experimental class achieved SL scores in the very high category, while the control was in the high category with mean scores of 81.11 and 71.67, respectively. The scores showed a significant difference based on the unpaired t-test (Table 4). This finding aligns with previous studies but with a difference in the participating subjects. Despite being Senior High School subjects, implementing project-based learning–flipped classrooms for second-year engineering students increased their fundamental formative knowledge, enhanced problem-solving abilities, and produced better artefacts performance (design skills and creativity) compared to traditional PjBL (Chua & Islam, 2021). Another study with a contextual-flipped classroom approach on acid-base learning for 11th-grade high school students also achieved an SL competence of the very high category with an average score of 84.17 (Paristiowati et al., 2019). A PjBL model is a standard form of a contextual approach. Although the learning material of this study was different from those of Paristiowati et al. (2019), namely electrolyte-non-electrolyte solutions and acid-base, respectively, both are chemical science fields. Zhang et al. (2021) found that the flipped classroom had the best effect size for science than the arts and engineering fields.

The results of this study support previous studies that flipped classrooms made the learning process more effective and improved scientific literacy (Paristiowati et al., 2019; Susanti et al., 2020). Students achieved SL competence indicators of explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically 72.49, 88.12, and 91.83, respectively (Paristiowati et al., 2019). The flipped classroom developed the students' broader literacy and gave them prior knowledge to be better prepared for learning and problem-solving tasks. Learning with this method made students enthusiastic and obtained good scientific literacy skills. Students also learn more with the approach than with ordinary learning. They may enjoy group work and discussions, interaction with peers, and feel more comfortable asking questions, presenting, or solving problems; hence, they become more independent and active (Monaghan-Geernaert, 2019). Flipped classroom effectively helped students in mastering the knowledge and increased their ability to independently solve problems (Enfield, 2013; Zhang et al., 2021).

Table 1 shows that using PjBL without flipped classrooms significantly increased scientific literacy from the low to the high category, with an *N-gain* score of 0.62 (moderate category). Although the *N-gain* score of the experimental class with the PjBL-FC was slightly higher, 0.74 or high category. However, PjBL independently improved scientific literacy through its stages. This model was designed to train students' ability to solve authentic problems in projects or practical solutions scientifically. Skills such as critical, creative, and logical thinking are applied to this problem (Brundiers & Wiek, 2013).

The success of the PjBL-FC in improving students' scientific literacy was also supported by the use of learning resources that were very familiar to students in their daily lives, namely the wetlands environment. According to Mahmudah and Sholahuddin (2016), this condition provided interesting, motivating, and meaningful learning. Meaningful learning occurs because students can connect their experiential knowledge with the new information they learn in the classroom. Therefore, the object or context closest to students helps facilitate the process. This meaningful approach results in deep learning (Sholahuddin, 2015) and improves the students' scientific literacy (Nofiana & Julianto, 2018).

Figure 1 shows that almost all scientific literacy indicators have reached the high to very high category except for the ability to propose a hypothesis. This ability is part of evaluating and designing scientific research skills (Table 1), which are commonly proven as low based on a previous study (Sholahuddin & Shadriyah, 2017). This finding has strengthened the previous study of Sholahuddin et al. (2021). However, it differs from the findings of Paristiowati et al. (2019) that the lowest SL achievement of students is an indicator related to the ability to explain scientific phenomena. The ability to explain scientific phenomena only requires students to understand and apply chemical concepts to explain everyday life events, such as the reaction rate of the ship hulls rusting and the phenomenon of the electrical conductivity of rivers or seawater. Meanwhile, proposing a hypothesis indicator requires analysing and relating concepts and variables to the given problem. This ability is a complex process skill that is difficult for most students to be mastered. The following is an example of a question given to measure the proposed hypothesis ability: *"Lime is extracted to test its electrical conductivity to illuminate an indicator lamp. The extracted solution is put into three different beakers of 10 mL each. The first beaker contains 10 mL of "kuit" lime solution, the second contains 10 mL of "kuit" lime solution with an additional 3 mL of water, and the third contains 10 mL of "kuit" lime solution with 6 mL of water (Figure 4). Based on the above statement, propose a correct hypothesis!"*

One of the students' correct answers was, "*The more water is added, the less the acidity and the smaller the electrical conductivity*". Meanwhile, the example of incorrect answers is "*Kuit" lime is used as a tool to test the electrical strength it produces against the light of a lamp*". Students who answered incorrectly showed that they needed help understanding the nature of the hypothesis. These skills need to be trained for proper understanding and are accustomed to thinking analytically and logically through chemistry or science learning.

The results showed that although the PjBL model independently facilitated strengthening students' scientific literacy, but the integration of flipped classrooms was proven to improve their achievement. This fact is due to the efficiency of the time used for learning. Students can take advantage of time outside the classroom to understand the relevant concepts and design the problems solving in projects. The time available in the class can be used to make discussions between students and or teachers regarding the project completion. Therefore, achieving scientific literacy learning outcomes using the PjBL-FC becomes more effective.

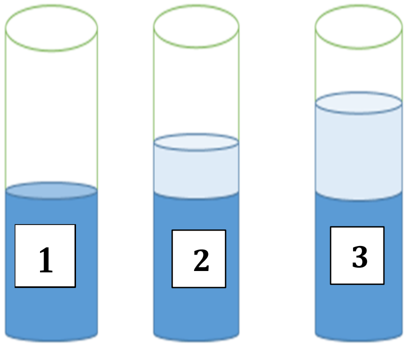

Figure 4. The Diluting Solution

Students also responded positively to implementing the PjBL-FC using wetlands environmental learning resources. This positive response is because the integrated model, approach, and learning resources facilitated their activeness and creativity. The learning stages also motivated them to explore new knowledge related to chemical materials. Enthusiasm and curiosity can be seen during learning and problem-solving activities in the form of projects. Students feel a more open learning atmosphere and a contextual environment different from previous chemistry learning. Previous studies also found that students were interested in and preferred learning using the flipped classroom approach. This learning made the process more enjoyable, interactive, and efficient. Besides, flipped classrooms increase motivation and allow students to learn in their way, specifically in understanding the concept being studied (Holzinger, 2016; Mahmudah & Sholahuddin, 2016).

Traditional learning may equally support content knowledge acquisition as a type of inquiry-based-flipped classroom learning such as PjBL-FC. However, PjBL-FC may cause more learning at higher concept application levels, general problem-solving, creative thinking, and collaboration (Love et al., 2015). Moreover, when supported by the surrounding environment as a learning resource, it provides meaningful learning; hence, knowledge, skills, and attitudes will be well constructed and have longer retention.

The learning content, source, and platform used to facilitate learning using the flipped classroom approach are unlimited. The sources include offline or online and simple media such as modules, videos, or interactive multimedia. Thus, the PjBL-FC can be a solution to overcome the learning problems experienced by students during the pandemic, make learning more effective and fun, provide wider self-actualization and make students more independent in learning (Purwadi et al., 2021). PjBL is an inquiry strategy designed for students with good self-directed learning. Therefore, applying the strategy to students of lower educational levels requires adaptation by reducing the problems' complexity and giving a step-by-step scaffolding (Ernawati et al., 2022) according to their needs and ability.

Conclusion

This study showed that students' scientific literacy in the class that applied the project-based learning flipped classroom (PjBL-FC) was better than those who applied the PjBL model. The difference between PjBL-FC and PjBL is the former's flipped classroom activities. The pre-class activities of PjBL-FC are conducted independently outside the classroom with teachers' guidance through relevant worksheets and videos. Meanwhile, in both participating classes, learning activities were conducted in the form of face-to-face. Students in the PjBL-FC and PjBL classes achieved literacy scores in the very high and high categories, respectively. The N-gain score showed their SL increased by high category in PjBL-FC and moderate in PjBL. All the indicators reached the high to the very high category, except for the ability to propose a hypothesis, which is still moderate. Based on these findings, it can be concluded that the PjBL model independently facilitates students' SL and meaningful learning. However, the integration of flipped classrooms (PjBL-FC) makes it better than only PjBL. This fact is related to the efficiency of time spent mastering concepts, designing, and completing projects outside and inside the classroom. Students have also experienced a motivating and meaningful learning process by using environmental learning resources close to students. Thus, combining a PjBL-flipped classroom with environmental learning resources around students can improve students' scientific literacy better than the PjBL strategy alone.

Recommendations

These findings contribute to the theory of Social Constructivism that students' ability to construct knowledge through project-based learning can be increased by combination with other strategies such as flipped classrooms. Practically, PjBL-FC can be effectively used by teachers to foster students' scientific literacy through science learning. However, this study has yet to explore the effectiveness of each learning tool, such as teaching materials, learning videos, and student worksheets used in the PjBL-FC strategy. In addition, face-to-face activities in this study were carried out through an offline platform only. Future studies can qualitatively elaborate on the effectiveness of teaching materials, learning videos, and worksheets in achieving learning outcomes. Furthermore, it can elaborate on the effectiveness of the PjBL-flipped classroom strategy by using an online platform to train scientific literacy.

Limitations

This study used a limited sample, namely two classes in a school. However, the sample was considered a representative of Senior High School students in Banjarmasin City, South Kalimantan, Indonesia. Therefore, further dissemination and trials are needed by involving more schools to explore in-depth information on phenomena that occur in the learning process. These trials will support the conclusions about the effectiveness of combining the PjBL strategy with the flipped classroom in improving scientific literacy.

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Authorship Contribution Statement

Sholahuddin: Concept and design, data acquisition, statistical analysis, data analysis/interpretation, drafting manuscript, editing/reviewing, final approval. Anjuni: Data acquisition, statistical analysis, data analysis/interpretation. Leny: Critical revision of manuscript, editing/reviewing. Faikhamta: Critical revision of manuscript, editing/reviewing.

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