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Students' Scientific Literacy as the Effect of Project-Based Learning Using a Simple Colloid Product

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Abstract. Scientific literacy is still to be a problem for most worldwide students, including in Indonesia. This study used simple colloid products as a learning source in a project-based learning setting to train students' scientific literacy. The non-equivalent control group design research was applied in two different classes of grade 11 SMAN 4 Banjarmasin involving 69 students. Data collection used scientific literacy test instruments that are valid (CVR index of 1) and reliable (α-Cronbach index of 0.91). Research data were analyzed by using descriptive and inferential t-test methods. The measured scientific literacy competencies include explaining scientific phenomena, evaluating and designing scientific research, and interpreting data and scientific evidence. This study concluded that the students' scientific literacy of project-based class was better than the expository class by good and moderate category. Exploring more sources of learning chemistry from industrial products is necessary to generate scientific awareness that chemistry helps build our real life. At the same time, it will produce meaningful learning to form scientific literacy.

INTRODUCTION

Chemistry learning in schools still tends to emphasize how to transfer knowledge to the students. In this case, learning the concepts, laws, and chemical theory were carried out without providing direct experience in applying concepts through actual problem solving [1]. A lesson achievement is primarily determined by how well students can answer textual questions and use algorithms to apply chemical concepts compared to achieving higher competencies such as critical thinking, creative thinking, problem-solving skills, and scientific literacy. Mastery of the knowledge aspect has not touched higher-order thinking levels, including exploring concepts to the submicroscopic chemistry level. Meanwhile, most studies showed that using strategies involving students in finding concepts such as learning Cycle 5E and others could facilitate mastery of deep chemical concepts to the level of submicroscopic representation. It has an impact on students' critical thinking skills [2] as part of scientific literacy.

Operationally scientific literacy can be a person's ability to use scientific knowledge and processes to identify questions and draw evidence-based conclusions to understand and help someone make decisions about the natural world and social problems through problem-solving [3, 4, 5]. A person will play a role and be involved in science and scientific ideas as a reflective citizen by scientific literacy. This scientific literacy includes the competence to explain phenomena, interpret data and evidence, evaluate and design scientific investigations [4, 6]. Scientific literacy is essential for everyone to play an essential role in society, both as citizens and as leaders in the future.

Most students still have scientific literacy at the primary level or level 2 of 6 levels on the PISA scale [7]. In this condition, students are just beginning to demonstrate the competence of science to engage in reasoned discourse about science and technology. Students demonstrate basic or everyday scientific knowledge and an essential scientific inquiry to apply in familiar contexts. Students' skills progressively expand to less familiar contexts and more complex knowledge and understanding at higher levels of scientific literacy.

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Students' low scientific literacy ability is strongly influenced by the learning strategies applied by the teacher in the classroom [8]. Teacher-centered learning and minimal activity of finding concepts or solving scientific problems are certainly difficult in developing students' literacy skills. Science learning must be returned to the nature of science itself. Science must be studied as scientists discover and develop the science. The process involves three elements of science at once, namely product, process, and scientific attitude. Learning must be able to facilitate students to carry out scientific stages in solving problems. Activities such as formulating problems, stating hypotheses, designing experiments, collecting data, drawing conclusions, and communicating the discovered chemistry concepts should be part of the learning process.

Inquiry-based learning strategies or problem-solving, including project-based learning (PjBL), have been proven to effectively train students' academic performance in the chemistry field, including their scientific skills. The PjBL strategy can shift passive or teacher-centered learning to active or student-centered learning [9]. PjBL focuses on project completion, encouraging students to learn critical concepts and principles of a discipline and then apply them in real situations [10, 11]. PjBL can also develop social skills, problem-solving skills, and scientific literacy [12, 13]. Students also habituate a hard work behavior when they are involved in problem-solving. In addition, students can articulate the value of their work and its application to “real world” settings [14]. Therefore, students not only acquire knowledge but also develop their scientific literacy skills.

Traditional chemistry learning has provided a meaningless, tedious, and less deep learning process. Because meaningful learning only occurs if students connect knowledge and ideas in their cognitive structures with new information being learned [15]. Even if using learning resources, it is still limited to traditional sources such as laboratory infrastructure and kits. Even though there are many potential learning resources in the environment around students, which is beneficial for schools that do not have good chemistry laboratories. They can be utilized as a learning resource that significantly affects students' mastery of chemical concepts [16]. The use of traditional foods as colloidal learning resources in project-based learning settings has facilitated meaningful learning and enhanced students' scientific literacy [17].

Chemistry learning resources can be in local and modern industrial products, which are an inseparable part of our everyday lives. These industrial products can be found easily in shops and supermarkets around us. Using well-known industrial products, students learn how the final product has been packaged and produced. These learning resources can be used as a stimulus to understand how these materials are produced through chemical processes. Chemistry learning becomes very contextual and comprehensive. Thus learning does not provide only knowledge but also trains students of thinking and problem-solving skills.

Superficial products such as ice cream and jelly, which are very well known and easy to obtain, can be a stimulus to be explored in chemistry class to make exciting and meaningful learning. Learning needs to be presented simply with simple learning resources as well. Because learning that is too complex in terms of interaction, information, problems solved, and learning resources can cause overload capacity in our working memory, so learning is not practical. In addition, learning that utilizes or connects the students' prior knowledge will also develop their memory capacity [18]. Thus, using learning resources that are well known to students and using clear problem-solving stages will make students achieve the learning goals quickly. By using learning resources such as daily food products, students can learn How to produce traditional foods? What are the materials needed? What is the correlation of the material with colloidal concepts? It will provide an exciting activity in the context of a project-based learning strategy. This study examined students' scientific literacy differences between those who learned colloid concepts applying project-based and expository learning strategies using simple colloidal industry products as a learning source. Expository learning strategy is the traditional strategy most often used by teachers which emphasizes the achievement of knowledge competencies. Meanwhile, PjBL emphasizes a student-centered learning process and collaborative problem/project resolution.

METHOD

The research design applied is a non-equivalent control group. This study aims to analyze the differences in scientific literacy between students who use project-based learning strategies and those who use expository strategies with simple colloid industrial product learning resources. The research involved two classes, namely class XI MIPA 1 (34 students) and class XI MIPA 2 (35 students) as experimental and the control class, respectively. The experimental class was given intervention in a PjBL learning strategy, while the control class was an expository strategy. Students' scientific literacy ability was tested before and after the chemistry learning took place.

This chemistry colloid learning by using the PjBL strategy was carried out in collaboration mode along 4 class meetings. There were six groups in every class; 3 groups completed an ice cream-producing project, and the other three groups a jelly-producing project. On the other hand, the expository learning strategy emphasizes delivering material verbally from a teacher to students to master the subject matter optimally. The steps of that two strategies were presented in Table 1.

TABLE 1. The steps of PjBL and expository learning strategy

No	PjBL Strategy		Expository Learning Strategy	
	Steps	**Learning Activities**	**Steps**	**Learning Activities**
1	Project determination	At this stage, students determine the theme/topic of the project based on the project assignments given by the teacher.	Preparation	The teacher prepares students to accept learning by giving positive and conveying learning objectives.
2	Project design	Students design the steps of project implementation activities, from start to finish, and also their management.	Presentation	Teacher delivery of learning material to students.
3	Scheduling	Each student does the task according to the division of work that their group has designed.	Correlation	Teacher connects learning materials with somethings that allow students can relate to their perior knowledge.
4	Project completion	Each student does the task according to the division of work that their group has designed.	Conclusion	Students conclude with the teacher's scaffolding by taking the essence of learned concepts.
5	Presenting finished project	Students present/publish finished-project to other students and teachers.	Application	The teacher collects information about students' learning mastery by giving assignments or tests.
6	Evaluation of the process and results	Evaluation of the process and results. Teachers and students reflect on the activities and finished-project that have been carried out.		

Research data collection used scientific literacy test instruments that are valid (CVR index of 1) and reliable (α-Cronbach index of 0.91). Measured scientific literacy competencies include explaining scientific phenomena, evaluating and designing scientific research, and interpreting data and scientific evidence. In addition, students were also given a questionnaire to find out how well they responded to the learning that was followed.

Scientific literacy scores were categorized as follows: 0-20 as shallow categories, 21–40 as low category, 41–60 as moderate category, 61–80 as high category, and 81–100 as a very high category. The increase of students' scientific literacy was determined based on n-gain values <g>: <0.3 as low category, 0.3 <(g) <0.7 as medium category and 7 as high category [19]. Furthermore, an independent t-test was used to test students' scientific literacy difference between experimental and control classes [20]. The research hypothesis being tested is whether there is a significant difference between the scientific literacy of students who study using PjBL strategy and those who use the expository learning strategy.

RESULTS AND DISCUSSION

Before and after learning with two different strategies was carried out, a student scientific literacy test was conducted and the results are presented in Table 2. Table 2 showed that experimental class students have a higher post-test score of scientific literacy in a high to the very high category than the control class.

TABLE 2. Pre-test and a post-test score of students' scientific literacy

Score Interval	Category	Experiment				Control			
		Pre-test		Post-test		Pre-test		Post-test	
		f	%	f	%	f	%	f	%
80.1 – 100	Very high	-	-	9	26.47	-	-	-	-
60.1 – 80	High	-	-	19	55.82	-	-	15	42.85
40.1 – 60	Moderate	-	-	6	17.65	-		10	28.57
20.1 – 40	Low	4	11.76	-	-	2	5.71	10	28.57
0 – 20	Very low	30	88.24	-	-	33	94.29	-	-
Total		34		34		35		35	

The achievements of each scientific literacy indicator can be seen in Table 3. Based on Table 3, the average of students' scientific literacy has increased from the very low to the high category for experimental class, meanwhile from the very low to the moderate category for control class.

TABLE 3. Achievements of each scientific literacy indicator

No.	Scientific Literacy Indicator	Achievements (%)			
		Experimental Class		Control Class	
		Pre-test	Post-test	Pre-test	Post-test
1	Recalling and applying appropriate knowledge	61.8	100	46.7	91.4
2	Identifying, using, and producing explanatory and representational models	12.7	79.4	3.8	8.6
3	Processing and justifying the appropriate predictions	7.8	58.8	6.7	426
4	Explaining the potential implications of scientific knowledge for society	3.9	81.4	2.9	68.6
5	Identifying questions (problems) from exploration of particular scientific research	20.6	87.3	8.6	81.9
6	Proposing a way of exploring scientific problem	2.0	62.7	2.9	57.1
7	Evaluating ways to investigate scientific question	3.9	53.9	2.9	31.4
8	Analyzing, interpreting, and drawing conclusion	19.6	92.2	2.9	71.4
9	Identifying assumptions, evidence, and reasons of related scientific statements	3.9	59.8	2.9	47.6
10	Evaluating scientific arguments and evidence from different sources	7.8	72.5	2.9	45.7
	Average	14.4	74.8	8.3	54.7

The increasing students' scientific literacy can be seen in the average value of n-gain in Table 4.

TABLE 4. N-gain of students' scientific literacy

No	Interval n-gain	Category	Frequency	
			Experimental Class	Control Class
1	<g> ≥ 0.7	High	15	1
2	0.7 > <g> ≥ 0.3	Moderate	18	29
3	<g> < 0.3	Low	1	4
	Average		0.71	0.51
			High	Moderate

The pre-test and post-test scores of scientific literacy showed that they were normally distributed and homogeneous. While the results of the t-test on the post-test scores of scientific literacy as presented in Table 5,

TABLE 5. t-Test result of students' scientific literacy score

Result	Class	dB	$\bar{X}$	SD^2	F_{count}	F_{table} ($\alpha = 5\%$)	Conclusion
Post-test	Experiment	33	74.51	216.59	6.08	2.00	Significant difference
	Control	34	54.95	131.25			

Based on the t-test analysis, the value of F_{count} is 6.08 > F_{table} is 2.00. Ho is that the two mean scores of scientific literacy are not different. However, Ho was rejected. Thus, it is concluded that there is a significant difference between the average scientific literacy scores of students in the experimental class and the control class after learning that applies the PjBL model with learning resources of food industry products.

Table 5 showed that the scientific literacy of the experimental class students who applied the PjBL learning strategy was better than the scientific literacy of the control class who applied the expository strategy. Both classes used the same learning resources, namely food industry products that are very well known to students (ice cream and jelly) as the material project. This result was supported by the distribution of literacy scores (Table 2) that the experimental class has more scores in the good to the very good category than the control class.

These results are the effect of differences in the characteristics of the learning process experienced by students through different strategies. The PBL strategy encourages students to be actively involved in exploring knowledge from various learning sources through collaboration in teamwork to solve real problems in projects. Thus, there is a training process through project completion activities for various skills such as collaboration and teamwork skills, independent learning and research, and problem-solving skills. In addition, through teamwork, students familiarize and develop other social attitudes such as trust, respect, and responsibility [21]. Full involvement in this process plays a vital role in improving overall achievement and success in their future.

Students gain meaningful learning experiences, which can improve scientific literacy, where they complete authentic projects directly related to everyday life. Other research indicated that scientific literacy would be further improved if using actual experiments in the learning process because students directly experience each process and try to explain the observed phenomena to construct their knowledge [22, 23].

The results strengthen previous studies that the PjBL strategy can improve students' scientific literacy [17, 24]. The difference between this study and the others is the use of simple materials and projects. The simplicity of the project and the materials used as learning resources make the chemistry learning process easier to be understood by students and even make it more interesting. Therefore, students also gave an excellent response to project-based learning on this colloid concept. Based on the questionnaire given to students at the end of the lesson, as many as 60% of students in the experimental class stated that learning with PjBL with learning resources for food industry products was very good, 38.24% was good, and the remaining 1.76% said it was pretty good. It means that the learning strategy applied is advantageous dan make the student learn quickly. In the control class, 11.6% said it was excellent, 67.30% said it was good, 14.05 said it was sufficient, and the remaining 1.76 said it was not good. This students' response is also in line with the fact that the two strategies have a different effect on students' scientific literacy learning outcomes, as described above.

Project-based learning focuses on mastering knowledge through problem-solving that encourages collaborative student involvement. Students are facilitated to explore learning resources, formulate problems, design problem solving, explain the finished project and communicate it to the community or other people. Students relate their knowledge with the new knowledge they are learning to produce authentic products through this process. Project-based learning is not the right strategy if the goal of learning is only to mastery of knowledge. This strategy is needed if the learning objectives are to provide other skills (soft skills) useful for the students and their readiness to live in society.

When students produce jelly, they have to mix agar powder with water, then mix the mixtures. When ingredients are mixed the colloid occurs which produces a colloidal system (Fig. 1). What type of colloid is it? Students need to explore the learning source about colloids. Jelly product is an example of a colloid whose type is a solid emulsion in which the dispersed phase is liquid (water), while the dispersing phase is solid (agar powder). Jelly is a type of lyophilic colloid, where the dispersing substance "gelatin flour" binds the dispersing agent "water" to produce a very thick gel. In this case, student analysis is correct. In the process of presenting the project results, the discussion was deepened through the teacher's guide to classify the types of other colloids. Thus students have learned knowledge and skills from what they were experienced directly. Students collaborate with others, from formulating projects, planning schedules, experimenting, to communicating project results. Through this project, they have learned not only knowledge but also various soft skills and other scientific attitudes including critical thinking, creative and problem-solving skills, discipline, responsibility, etc.

(a) (b) (c)

FIGURE 1. Students' project of jelly production, (a) mixing agar powder with water, (b) producing colloidal system, (c) forming jelly with a certain shape

There are inappropriate terms made by students, for example, "There is gelatin contained in the agar which is an emulsifier that functions as an emulsifier and water binder". The term emulsifier in a chemical context is used to describe a substance that causes two or more substances to be dispersed to form a colloid. In this case, the gelatin is a water-miscible material, not an emulsifier. In simple terms "emulsifier" is the "third additional material" which is in charge of uniting immiscible ingredients. For example, soap is an emulsifier between oil and water to form a colloidal dispersion. In everyday application, the detergent principle is to emulsify dirt "which is generally mixed with oil/sweat" with water so that the dirt can be cleaned and rinsed off the fabric surface. To become an emulsifier, a molecule or substance must have the ability to dissolve or mix in two or more substances that must be emulsified, because of the functional groups on the molecule it has. Soap or detergent molecules have a polar functional group, -CHOO- carboxyl, which can combine with water, and have a nonpolar functional group $-(CH_2\text{-}CH_2\text{-})n$ – a carbon chain, which makes them miscible with oils. Likewise, when students produce ice cream, they also learn various skills, attitudes, and knowledge about colloids. This kind of learning can be developed so that learning becomes meaningful, deep, fun, and effective to achieve many learning objectives.

In practice, project-based learning requires high self-control for teachers not to "deliver the concept directly" but rather to facilitate so that students succeed through each stage of learning and find concepts through project completion. Of course, this strategy requires a longer time than the expository strategy, so it requires excellent learning time management. However, this strategy allows the achievement of learning outcomes in the form of competencies that are very important for students' future. Project completion activities that require a long time can be conducted at home, and students bring documentation of activities to class for discussion and deepening. This means that project-based learning can use a flipped-classroom approach to achieve more effective learning [25, 26]. The most frequently reported advantage of the flipped classroom is the improvement of student learning performance [27, 28, 29, 30]. Flipped classrooms are proven to be successful in training scientific literacy and increasing students' enthusiasm for learning [31].

CONCLUSION

The application of project-based learning strategies can improve students' scientific literacy better than expository learning strategies. Using simple colloidal learning resources around students such as ingredients for making ice cream and jelly as project completion provided more meaning, fun, and easy learning. Increasing students' scientific literacy resulted from differences in the characteristics of the learning process experienced by students through different strategies. The PBL strategy encouraged students to explore knowledge from various learning sources in teamwork to solve real problems as the projects. Meanwhile, learning with expository strategies emphasized the achievement of knowledge with the higher teacher's role than the students conveying the colloid concept. Because project completion needs more time than expository learning, the teacher needs to manage the time and apply flipped classrooms to make the learning efficient. It is necessary to explore more sources of learning chemistry from industrial products to generate scientific awareness that chemistry helps build our real life. At the same time, it will produce meaningful learning to form scientific literacy.

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