

Application of Project-Based Learning (PjBL) to Improve Critical Thinking Skills and Students' Learning Independence on the Making of Colloids in Dispersion

Gita Annisa Desiana¹, Sulastr^{1} and Syahrial¹*

¹Natural Science Education, Faculty of Mathematics and Natural Science, Syiah Kuala University, Banda Aceh, 23111, Indonesia

**E-mail: sulastr@fkip.unsyiah.ac.id*

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Abstract

Critical Thinking Skills (CTS) and student learning independence are two things related to the learning process. The low independence of student learning affects critical thinking skills in solving a learning problem. A project-based learning model can improve critical thinking skills and independent learning. This study aims to analyze the application of the PjBL model to manufacture colloids to improve students' critical thinking skills and independent learning at MAN 1 Banda Aceh. The type of research used is quasi experimental. The samples of this study were students of natural science two 11th grade as control class and students of natural science four 11th grade as experimental class, which had normal distribution and had the same variance. The instruments of this research are the CTS test questions and learning independence questionnaires. The results show that applying the PjBL model can improve critical thinking skills (CTS) with an average N-gain value in the medium category, then the CBC analysis of indicators is in the high category. The results of testing the CTS hypothesis for experimental class and control class students are also significantly different, meaning that the CTS model can improve students' critical thinking skills. The analysis of student learning independence results obtained an average score of N-gain, including the medium category. The results of the hypothesis test of student learning independence in the experimental and control classes are also significantly different, meaning that the PjBL model can increase learning independence. The results obtained prove that the PjBL model can improve CTS and learning independence better than in the control class.

Keywords: critical thinking skills, independent learning, PjBL model

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1. Introduction

Chemistry covers everything about matter which includes composition, structure and properties, changes, dynamics, and energy of substances that require skills and reasoning in studying them (Kharismawan et al., 2018). One of the chemistry learning materials taught in schools is colloids. Colloidal material is a chemistry subject that is given in natural science 11th grade senior high school which has a lot of memorization (Fajri et al., 2012). In addition, the characteristics of this material are mostly in the form of concepts that have many

applications in everyday life. This is in accordance with Permendikbud (minister of education and culture) number 24 of 2016 concerning Basic Competencies that students must have in colloid material, namely classifying various types of colloid systems, and explaining the uses of colloids in daily life based on their properties and making food or other products in the form of colloids or involves the colloidal principle.

However, based on the results of observations and interviews with several teachers at MAN 1 Banda Aceh, it shows that there are problems

with student learning abilities in chemistry learning. It is proven from the average national exam scores of students who are still in the less category. The low score of the National Examination affects the students' lack of critical thinking skills. In fact, the 2018 National Examination Results Executive Summary data from the Education Assessment Center, Research and Development Agency, Ministry of Education and Culture (2018) shows that the preparation of the National Examination consists of three levels. At the first level, namely knowledge (C1) and understanding (C2), the second level is application (C3), then at level 3, namely reasoning or included in the three cognitive domains of analysis (C4), synthesis (C5) and evaluation (C6). Based on the results of the review, it proves that the UN questions are included in the category of critical thinking questions, because the preparation of questions consists of C4, C5, and C6.

Critical thinking is one part of 21st century learning skills. Critical thinking consists of the ability to think logically, reflectively, and productively to assess situations. Critical thinking is an act of active thinking that leads students to be able to create, apply, analyze, synthesize, and evaluate concepts rather than just receiving ideas or information, so that students are easier to think about. In depth the existing problems, especially regarding fundamental life issues ((Ennis, 1993); (Hakim et al., 2018); (Sellars et al., 2018); (Sumarni et al., 2016)). Critical thinking is included in the realm of higher-order thinking skills that have the potential to increase students' critical analysis power. Increasing students' critical analysis power is closely related to making the right decisions (Andayani et al., 2020) with increasing students' intellectual abilities (Setiawati et al., 2017). Critical thinking is a high-level skill that is important for solving complex and sharp problems that require in-depth analysis (Wardani et al., 2019). These skills will help students to master test material with a higher level of difficulty, for example the entrance exam for public universities (Reza et al., 2021).

In addition to the lack of critical thinking skills in students at MAN 1 Banda Aceh. Based on the results of interviews, students also have low independence influenced by a lack of confidence in students in doing assignments or answering questions independently. The data on student reviews in natural science four 11th grade at MAN 1 Banda Aceh shows that the number of students who achieved the KKM were 12 people (31.6%) and students who had not reached the KKM were 17 people (68.4%) out of 38 students. The interview results strengthen the data above, namely students who are confident in their abilities when working on questions <50%. This is due to the habit of students overcoming the difficulties they experience by asking their friends who understand better without trying to do it themselves first. There are still some daily tasks given by the teacher to be done at home who do not collect according to the agreed time.

Independent learning is an important thing also grown through learning. There are three stages that must be carried out in increasing learning independence including; (1) observe and monitor independently, (2) compare their position with certain standards, and (3) provide positive and negative self-responses (Nafisa et al., 2021). Learning independence is a learning activity carried out by someone with the freedom to determine and manage their own teaching materials, time, place, and utilize the necessary learning resources (Loeng, 2020).

Students who have high learning independence are able to manage their own learning activities starting from the preparation, implementation, and evaluation stages (Kurniawan et al., 2018); (Aulia et al., 2019). The reality in the current learning process is that there is still a lack of independence or lack of student initiative to learn on their own, do not have high self-confidence and think critically to solve problems (Yuliasari, 2017). This proves that the low independence of student learning affects critical thinking skills in solving a learning problem.

The PjBL learning model has an important role in improving students' critical thinking skills and character values (Rumansyah et al., 2019). Educators who are able to teach students to understand the values in lessons have carried out quality teaching and learning activities (Sulastri et al., 2018). Project-Based Learning teaches many important strategies for success in the 21st century. Students are encouraged to be self-directed learning as well as to work collaboratively to research and create projects that reflect knowledge. From accumulating appropriate new technology skills, to becoming proficient communicators and problem solvers at an advanced level, students will benefit greatly from this teaching approach (Bell, 2010).

Through the PjBL model in chemistry learning, it is no longer oriented towards understanding concepts but more emphasis on the application of chemical concepts to a project so as to produce certain products (Wenger, 2014). Students develop and hone mindsets by linking through phenomena in everyday life (Birgil, 2015) further (Ennis, 1993) says that students' critical thinking skills that must be improved consist of five indicators including; (a) basic support; (b) the bases for the desician; (c) inference; (d) advance clarification; (e) strategy and tactics.

The PjBL learning model is a learning model that prioritizes solving complex tasks, based on challenging questions, which involves students in designing, problem solving, decision making, or investigative activities, giving students the opportunity to work independently over a period of time and culminate in a product. or presentation (Devi et al., 2019). The independence of student learning that must exist in students includes; goal setting, technical readiness, time management, procrastination management, note-taking skills, task preparation, research skills, exam preparation and stress management (Khiat, 2015).

Based on the previous problems, a model is needed that is able to improve critical thinking skills and independent learning, especially in chemistry lessons. The topic of chemistry

about colloids is one of the potential chemistry topics, because it can be understood and practiced easily. Students are able to do work or projects in learning situations in order to improve their analytical power. Previous research conducted by (Hikmah et al., 2016) & (Hasbie et al., 2018) revealed that the project based learning (PjBL) learning model was able to improve critical thinking skills and student learning independence on colloidal system material.

This research focuses on the manufacture of food products using the working principle of making colloids. PjBL can improve research skills, communication skills and self-confidence. PjBL will improve students in processing information critically, critically thinking (Chuppa-Cornell & Zimmerer, 2017; (Walker & Li, 2016); (Ferrer-vinent et al., 2016); (Saliba et al., 2017).

2. Research Method

The type of research used is quasi-experimental. This method contains steps consisting of pretest, experiment and posttest. The population used was all students of class 11th grade MAN 1 Banda Aceh in the even semester of the 2020/2021 school year. The population is 228 people who are distributed into six classes, namely natural science one 11th grade, to natural science six 11th grade. The reason for choosing class 11th grade is because the material being tested is 11th grade material and the data for determining the sample can be selected according to the results of the mid-semester chemistry exam. The sample selection used a purposive sampling technique which was included in non-probability sampling (Etikan et al., 2016). The purposive sampling technique selects the sample intentionally with sample requirements based on the characteristics of the same chemical value to determine the control class and the experimental class (Fraenkel et al., 2011). The similarity in the nature and characteristics of this sample was selected from a population of students who had passed mixed material in 10th grade. The sampling technique was carried out through

normality and homogeneity tests showing that it came from a population that was normally distributed and had the same variance, obtained natural science two 11th grade as the control class and natural science four 11th grade as the experimental class.

The learning tools developed in this study consisted of the Learning Implementation Plan (RPP) and Student Worksheets (LKPD). The lesson plans were developed using PjBL learning steps with a scientific approach for the experimental class and direct instruction steps for the control class. After the RPP and LKPD were developed, they were then validated by two validators.

Colloid-making learning through PjBL was carried out in two meetings, with an allocation of 4 lesson hours (JP). The learning steps in this study are in accordance with those proposed by (Suranti et al., 2016), namely (1) students answer essential questions related to food products using colloidal working principles proposed by the teacher to encourage knowledge and ideas about the project to be worked on, (2) students make plans for food products to be carried out, as well as project work rules, (3) students make schedules in completing colloid-making projects, (4) activities while completing student projects are monitored by the teacher by giving colloid-making videos, (5) The results of project work carried out by students are given feedback by the teacher, (6) students together with the teacher at the end of the learning process reflect on the activities and results of projects that have been carried out.

The instruments used in this study consisted of critical thinking skills test questions and student learning independence questionnaires. The test instrument for critical thinking skills in this study is a question in the cognitive domain of categories C4 and C5 which consists of 30 questions. While the learning independence questionnaire instrument consists of 10 indicators and 46 statement items.

After the data is obtained, then the data is analyzed using a hypothesis test consisting of;

(1) normality test, (2) homogeneity, (3) mean difference test (t test) and (4) N-gain test.

3. Result and Discussion

3.1. Application of PjBL in Making Colloids

PjBL activities carried out by students at the first meeting started with listening to the classical colloid-making material by the teacher, determining the title of the project to be carried out, making plans for work procedures and the use of tools and materials, finally compiling a schedule for colloid-making project activities. The second meeting of PjBL activities started with students showing a video showing the results of colloid making, receiving feedback and ending with evaluating experiences.

The advantages of the PjBL model (1) encourage students to be challenged to solve real problems in the field through project activities, (2) students become active in learning, (3) student performance in completing projects is more organized, (4) students have more freedom in completing projects, (5) students are motivated to compete to produce the best products, and (6) students become more independent and have responsibility for the projects they are working on (by (Rauziani et al., 2016); (Novianto et al., 2018); (Daryanto, 2014).

3.2. Student Critical Thinking Skills

Critical thinking skills are students' thinking skills that involve reasoning and logic in solving problems, distinguishing problems, and being able to review information to plan problem solving strategies given. Students' critical thinking skills in this study were measured by five indicators (Ennis, 1993) including; (a) building basic skills (basic support); (b) give reasons for a decision (the bases for the decision); (c) conclude (inference); (d) make further explanation (advance clarification); (e) strategy and tactics. Students' critical thinking skills were measured using test questions. Based on the results of data analysis, the average pretest, posttest, and N-gain of students' critical thinking skills can be seen in Figure 1.

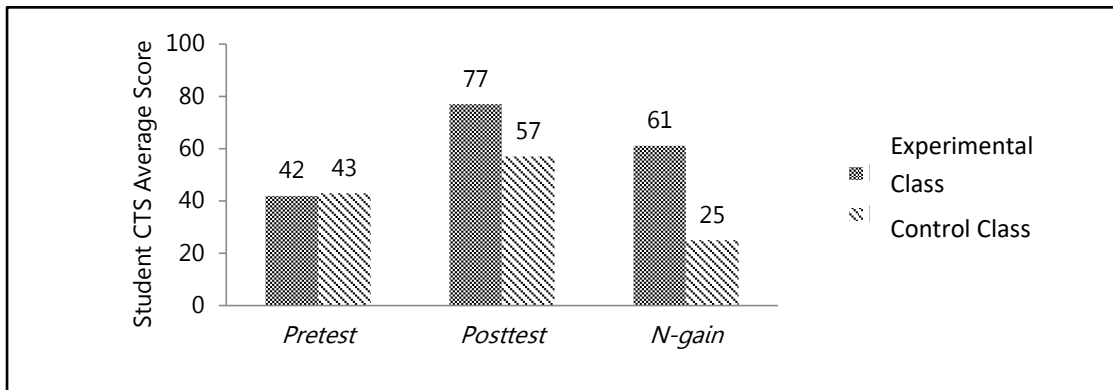


Figure 1. Student CTS Average Score

Figure 1 shows the results of the pretest, posttest, and N-gain analysis in the experimental class and the control class. Based on the results of data analysis, it was found that the average critical thinking skills of students after applying the Project based learning (PjBL) learning model in the experimental class was higher than the direct instruction model in the control class. This is in accordance with research conducted by

(Kusadi et al., 2020) that the project based learning (PjBL) model can improve students' critical thinking skills, because this model seems to involve more students in the learning process, so students are more active.

To find out the average pretest and posttest of students' critical thinking skills in each indicator of the experimental class and control class, it can be seen in Figures 1 and 2.

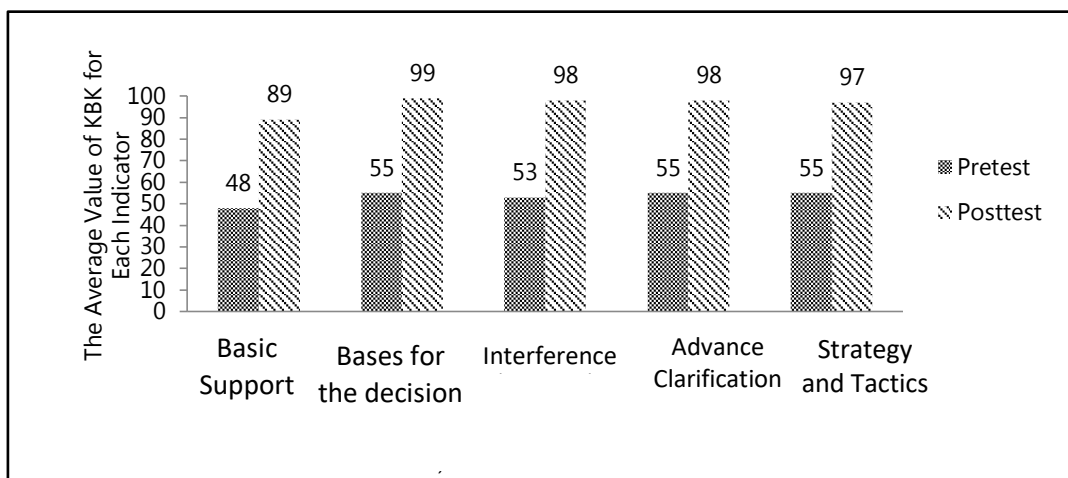


Figure 2. Student's CTS Average Results Per-indicator of Experimental Class

Figure 2 shows the results of the analysis of the average CTS of students in the experimental class before and after implementing the PjBL learning model. Based on the results of the analysis, it was found that the average CTS of students after applying the PjBL learning model was higher than in the control class. The average student results obtained > 80, meaning that the application of the PjBL model was able to improve students' critical

thinking skills better than the DI learning model.

This is in accordance with research conducted by (Aprianty et al., 2020) which states that PjBL is a learning model that uses projects as learning media and can help students develop psychomotor skills and understand concepts. The PjBL learning process demands the readiness of teachers to develop RPP and LKPD for project work. Students experience

the learning process and build their knowledge independently (Muntari et al., 2018).

The application of the PjBL model is able to improve students' CTS on each indicator. In the first indicator students are able to build basic skills with a score of 89. Second, students are able to give reasons for a decision with a score of 99. Third, students are able to conclude with a score of 98. Fourth, students are able to make further explanations with a score of 98. Fifth, students have strategies and

tactics with a score of 97. These results show that students' critical thinking skills on each indicator can be improved well, which is in line with research conducted (Sagala et al., 2020) that through the PjBL model students are invited to think broadly, seek information in order to find ideas that will be used to solve the problem.

To find out the results of the analysis of each indicator in the control class, before and after applying the learning treatment, it can be seen in Figure 3.

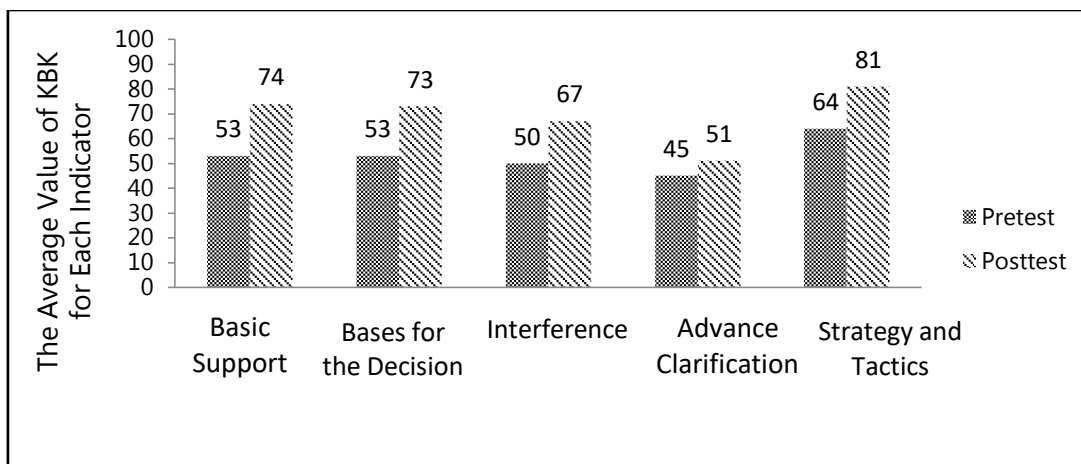


Figure 3. Student's CTS Average Results Per-indicator of Control Class

Figure 3 shows the results of the analysis of the average CTS indicator students in the control class. Based on data analysis, it was obtained that the average student CBC for each indicator after applying the direct instruction model obtained a score of <80. This means that the application of the learning model in the control class has not been able to improve

students' critical thinking skills, so the results measured on each indicator are still in the low category.

To find out the increase in students' CTS, each indicator in the experimental class and control class is calculated through the N-gain equation, with the results shown in Table 1.

Table 1. Result of N-gain Analysis Student CTS

Question Number	Indicator	N-gain Experiment	Category	N-gain Control	Category
CTS 1: 1,2,3,4,5,6,7	Build Basic Skill (<i>basic support</i>)	79	High	45	Medium
CTS 2: 8,9,10	Give reasons for a decision (<i>the bases for the decision</i>)	98	High	43	Medium
CTS 3: 11,12,13,14,15	Conclude (<i>inference</i>)	96	High	34	Medium
CTS 4: 16,17,18	Make further explanation (<i>Advance clarification</i>)	96	High	11	Low
CTS 5: 19,20	Strategy dan tactics	93	High	47	Medium

Based on data analysis, it was obtained that the N-gain CTS score of experimental class students was >70, meaning that students' critical thinking skills were included in the high category. While the results of the analysis of the N-gain CTS students in the control class obtained a score of <70, meaning that students' critical thinking skills are still in the low and medium categories.

After analyzing the results of N-Gain, in the experimental class and control class, the next

step is to test the hypothesis. Hypothesis testing used in the form of independent sample t-test, with prerequisites in the form of normality test and homogeneity of the data used.

The normality test used in this study is the Shapiro-Wilk test. The results of the Shapiro-Wilk normality test in the experimental class and control class can be seen in Table 2.

Table 2. Result of Normality Test *Shapiro-Wilk*

	Class	Shapiro-Wilk		
		Statistic	df	Sig.
Result of Student CTS	Experiment (Pretest)	.950	38	.086
	Experiment (Pretest)	.947	38	.073
	Control (Pretest)	.972	38	.442
	Control (Posttest)	.950	38	.091

The results of the analysis of the normality test using the Shapiro-Wilk technique proved that for all the experimental and control group data on the pretest and posttest, the Shapiro-Wilk sig value was > 0.05. So, the conclusion from this distribution is that the data in both classes are normally distributed. After doing the normality test, then the next step is to do the homogeneity test.

According to (Ismail, 2018) the homogeneity test of the data provides information that the research data for each data group comes from a population that does not differ much in diversity. The results of the homogeneity test in the experimental class and control class can be seen in Tables 3 and 4.

Table 3. Pretest Homogeneity Test Results Experiment and Control Class

		Levene Statistic	df1	df2	Sig.
CTS Result	Based on Mean	.071	1	74	.791
	Based on Median	.032	1	74	.858
	Based on Median and with adjusted df	.032	1	72.387	.858
	Based on trimmed mean	.073	1	74	.788

Based on table 3, the sig Based on Mean value is 0.791 > 0.05, so it can be concluded that the variance of the pretest data for the experimental class and the control class is the

same or homogeneous. To find out the posttest homogeneity test for the experimental class and the control class, it can be seen in Table 4.

Table 4. Results of Homogeneity Test of Experimental and Control Class

		Levene Statistic	df1	df2	Sig.
CTS Result	Based on Mean	2.708	1	74	.104
	Based on Median	2.200	1	74	.142
	Based on Median and with adjusted df	2.200	1	68.514	.143
	Based on trimmed mean	2.376	1	74	.127

Based on Table 4, the sig Based on Mean value is $0.104 > 0.05$, meaning that the variance of the posttest data for the experimental class and the control class is the same or homogeneous. To find out the test results of the average difference between the experimental class and the control class before and after applying the learning treatment, the independent sample t test was used.

The results of the independent sample t test of the experimental class and control class pretest data obtained a sig (2-tailed) value of $0.988 > 0.05$, meaning that the results of the pretest CTS students in the experimental class and control class were not significantly different. This means that the initial ability of the students' CTS before the learning treatment was applied to the two classes was the same.

Then the independent sample t test test of the posttest data of the experimental class and the control class obtained a sig (2-tailed) value of $0.000 < 0.05$, which means that there is a difference in the students' average CTS after applying the learning treatment. Based on the test results, it can be concluded that the application of the PjBL learning model can improve students' CTS compared to the control class. This is in line with the results of research proposed by (Zahroh, 2020) that the PjBL Learning model has a positive influence on students' critical thinking skills, because students are able to utilize various sources to

get the right procedures to be used in the projects carried out. Aldabbus (2018) said that project learning (PjBL) is not only limited to learning content knowledge of students, but is further developed in students' psychomotor and social skills, such as; seeking information from various sources, critical thinking, problem solving, self-evaluation, summarizing, and giving presentations are highly recommended for long term learning. Furthermore, this type of project offers an ideal context for students to study physical and chemical phenomena such as transport, surface phenomena, colloids and macromolecules (Santos et al., 2014).

3.3. Student Learning Independence

Student learning independence is a learning activity carried out by students, where students are more active in learning because they carry out learning activities independently and solve problems. According to (Khat, 2015) student learning independence consists of ten indicators including; goal setting, technical readiness, time management, procrastination management, note-taking skills, assignment preparation, research skills, class readiness, exam preparation, and stress management. To find out the results of the analysis of the pretest, posttest, and N-gain average student learning independence can be seen in Figure 4.

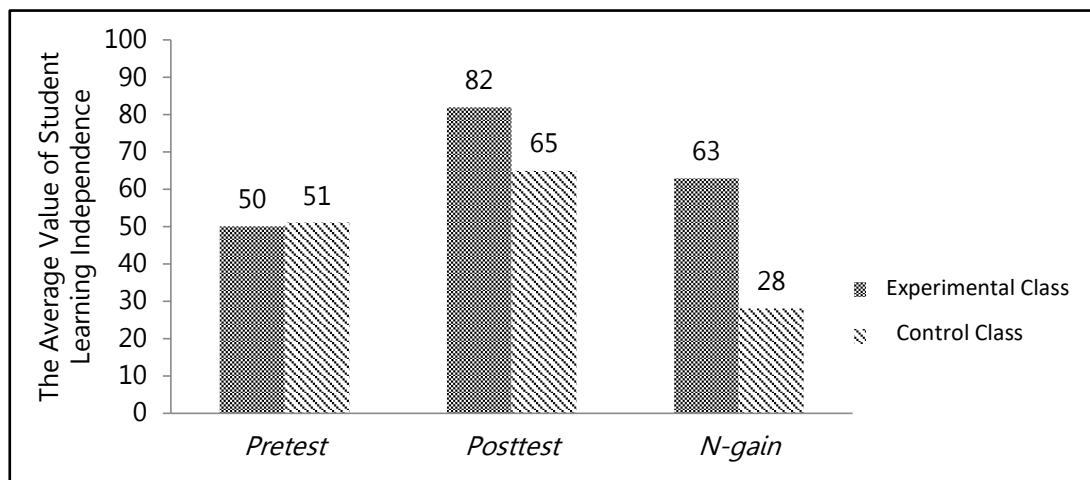


Figure 4. The Average Results of Student Learning Independence

Based on Figure 4, it can be seen that the average results of the experimental class students' learning independence after applying the PjBL learning model were higher than those in the control class. Then the results of the average N-gain analysis of the experimental class are in the medium category with a score of 63, while the control class is in the low category with a score of 28. The results of the analysis of student learning independence in both classes can be concluded that the application of the PjBL model is better used than the learning model. Conventional form of DI. This is in accordance with research conducted by (Ekawati et al., 2019) that learning independence is not only

focused on thinking, but helps individuals use their minds in drafting designs, choosing learning strategies, and interpreting their appearance so that they can solve problems effectively. In line with the research proposed by (Puspitasari et al., 2018) project-based learning has an influence on student learning independence, where students are more independent in the learning process and can create other products after the learning.

The results of the analysis of student learning independence on the ten indicators, both in the experimental class and the control class, can be seen in Figure 5.

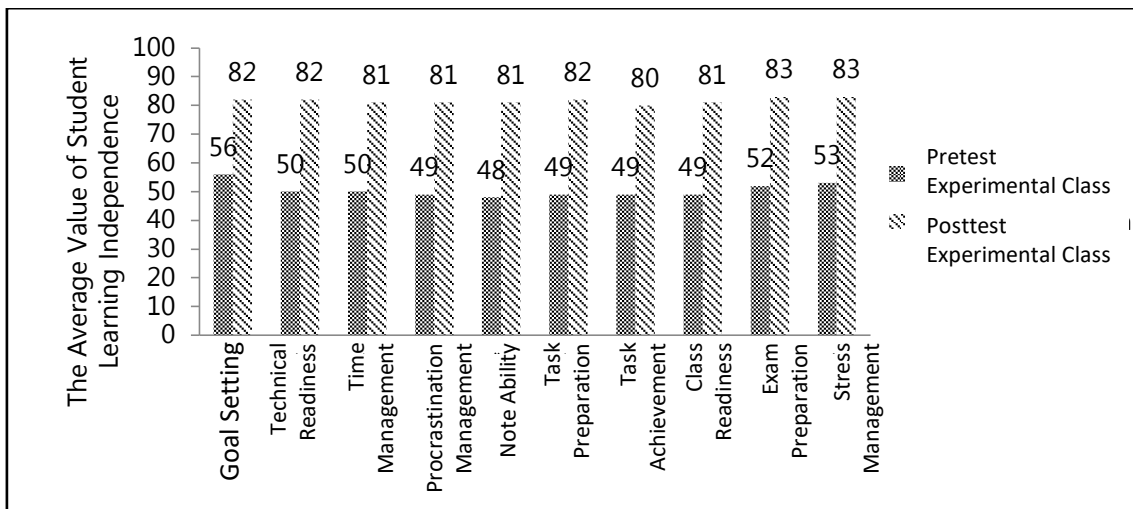


Figure. 5 The Average Results of Student Learning Independence Indicators of Experimental Class

Figure 5 shows the average results of student learning independence before and after implementing the PjBL learning model in the experimental class. The average results of student learning independence after applying

the PjBL model were higher than the control class (score > 80), so that the results of student learning independence were included in the good and very good categories. To find out the average student learning independence in the control class, it can be seen in Figure 6.

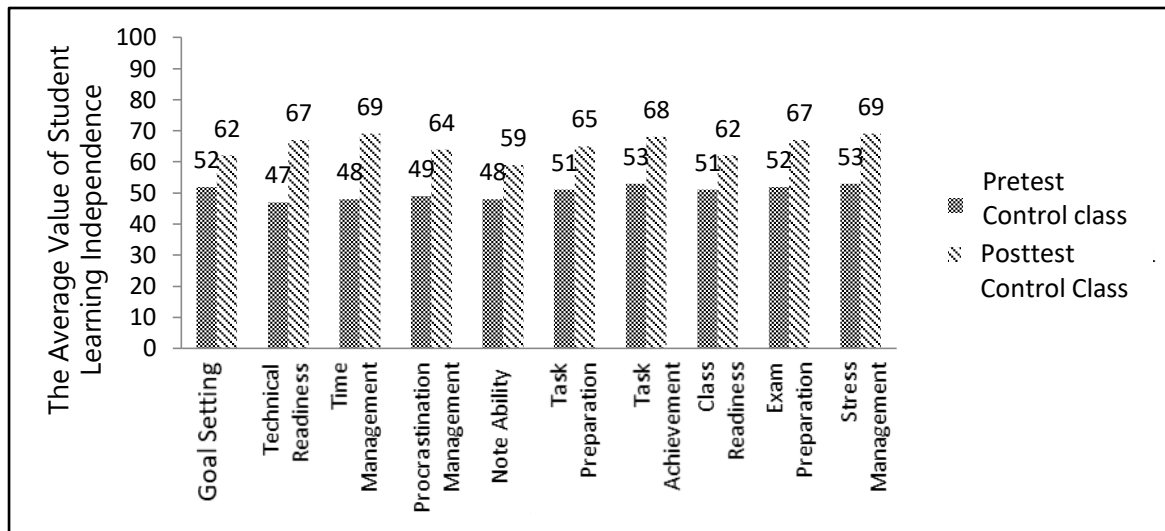


Figure 6. Average Results of Student Learning Independence Indicator Control Class

Figure 6 shows the results of the analysis of student learning independence indicators in the control class. Based on the results of the analysis obtained the average student learning independence through the application of the PjBL learning model obtained a score of <80. This means that the learning independence of

students in the control class is included in the sufficient and good categories.

Furthermore, to find out the increase in student learning independence in the experimental class and control class through the N-gain equation, as shown in Table 5.

Table 5. Results of N-Gain Analysis of Student Learning Independence

No	Indicator	N-gain Experiment	Category	N-gain Control	Category
1	Goal Setting	0,59	Medium	0,21	Low
2	Technical Readiness	0,64	Medium	0,38	Medium
3	Time Management	0,62	Medium	0,40	Medium
4	Delay Management	0,63	Medium	0,29	Low
5	Note-taking ability	0,63	Medium	0,21	Low
6	Task Preparation	0,65	Medium	0,29	Low
7	Research Ability	0,61	Medium	0,32	Medium
8	Class Preparation	0,63	Medium	0,22	Low
9	Exam Preparation	0,65	Medium	0,31	Medium
10	Stress Management	0,64	Medium	0,34	Medium

Table 5 shows the results of the N-gain analysis of student learning independence in the experimental class and the control class. The results of the experimental class N-gain analysis on each indicator obtained an average score of 0.6 including the medium category. Then the results of the N-gain analysis of the control class obtained an average score of 0.4, so it is included in the low and medium categories. Based on the results of the N-gain analysis, it can be concluded that student learning independence through the

application of the PjBL model is better than the DI model. This is in accordance with the research proposed by (Nahdliyati et al., 2016) that the PjBL model can foster independent learning in students, because the PjBL model makes learning more meaningful by actively involving students in the process of finding and solving problems during learning and instilling internal attitudes. On students, making students able to take the initiative to solve problems, and have the confidence to be able to learn on their own without the help of

others. To find out the results of testing the hypothesis of student learning independence, normality, homogeneity and independent

sample t-test tests were carried out. The results of the normality test of student learning independence can be seen in Table 6.

Table 6. Result of Normality Test *Shapiro-Wilk*

Class		Shapiro-Wilk		
		Statistic	df	Sig.
Student Learning Independence	Experiment (Pretest)	.963	38	.229
	Experiment (Posttest)	.961	38	.211
	Control (Pretest)	.982	38	.776
	Control (Posttest)	.975	38	.548

Based on table 6, the results of the Shapiro-Wilk normality test for students' learning independence in the experimental class and control class obtained a sig value > 0.05, so

that the data for both classes were normally distributed. Furthermore, the results of the homogeneity test on the pretest and posttest data of the experimental class and control class can be seen in Tables 7 and 8.

Table 7. Pretest Homogeneity Test Results Experiment and Control Class

		Levene Statistic	df1	df2	Sig.
Student Learning Independence	Based on Mean	1.622	1	74	.207
	Based on Median	1.620	1	74	.207
	Based on Median and with adjusted df	1.620	1	74.000	.207
	Based on trimmed mean	1.621	1	74	.207

Table 7 shows the results of the homogeneity test of the experimental class and control class data obtained by sig Based on Mean 0.207 > 0.05, meaning that the pretest data in both

classes came from the same variance or homogeneous. Then the results of the homogeneity test on the posttest data of the experimental class and control class can be seen in Table 8.

Table 8. Results of Homogeneity Test of Experimental and Control Class

		Levene Statistic	df1	df2	Sig.
Student Learning Independence	Based on Mean	1.612	1	74	.208
	Based on Median	1.682	1	74	.199
	Based on Median and with adjusted df	1.682	1	71.970	.199
	Based on trimmed mean	1.587	1	74	.212

Based on Table 8, the results of the posttest data homogeneity test for the experimental class and the control class obtained a sig Based on Mean value of 0.208 > 0.05, meaning that the posttest data in both classes came from the same variance or homogeneous.

data for student learning independence obtained a sig (2-tailed) value of 0.884 > 0.05. It can be concluded that the initial abilities of the experimental class and control class students are not significantly different or the same.

After doing the prerequisites in testing the hypothesis, namely normality and homogeneity tests, then the next step is to test the independent sample t-test. Based on the results of the analysis showed that the pretest

The results of the posttest data hypothesis test obtained a value of (2-tailed) 0.000 < 0.05, so it can be concluded that after applying the learning treatment in the experimental class and the control class it will produce

significantly different values. This is because the application of the PjBL learning model increases students' abilities more than in the control class. This is in accordance with research conducted by (Kizapan & Bektaş, 2017) that PjBL is one of the constructivist teaching strategies and is increasingly common in science education. PjBL is also able to create more freedom for students, so students can choose appropriate topics, resources to consult, division of responsibilities among group members and the way they design and display the final product (Aldabus, 2018).

4. Conclusion

Based on the results of previous studies, it can be concluded that the application of the PjBL model can improve students' critical thinking skills (CTS) with an average N-gain score of 61 in the medium category, then the average N-gain CTS score of indicator students >70 is included in the high category. The results of hypothesis testing for the experimental class and control class students obtained a sig (2-tailed) value of $0.000 < 0.05$, so it can be concluded that the CBC of students in the two classes was significantly different. The results of the analysis of student learning independence obtained an average N-gain score of 63 in the medium category. Then, the average score of N-gain indicator student learning independence is 0.6 medium category. The results of hypothesis testing of student learning independence in the experimental class and control class obtained a sig. (2-tailed) $0.000 < 0.05$, so that the students' learning independence in the two classes was significantly different. The results obtained prove that the PjBL model is able to improve CTS and student learning independence better.

References

Aldabus, S. (2018). Project-based learning: implementation & challenges. *International Journal of Education, Learning and Development*, 6(3), 71–79. Retrieved from

<https://www.eajournals.org/journals/international-journal-of-education-learning-and-development-ijeld/vol-6-issue-3-march-2018/project-based-learning-implementation-challenges/>

Andayani, Y., Zulkarnain, Z., & Hadisaputra, S. (2020). Promoting critical thinking skills of chemistry learning students using preparing doing concluding (PDC) learning models. *Journal of Physics: Conference Series*. <https://doi.org/10.1088/1742-6596/1521/4/042116>

Aprianty, H., Gani, A., & Pada, A. U. T. (2020). Implementation of project-based learning through stem approach to improve students' science process skills and learning outcomes. *JTK: Jurnal Tadris Kimiya*, 5(2), 144–152. <https://doi.org/DOI> : <https://doi.org/10.15575/jtk.v5i2.8370>

Aulia, L. N., Susilo, S., & Subali, B. (2019). Upaya peningkatan kemandirian belajar siswa dengan model problem- based learning berbantuan media Edmodo. *Jurnal Inovasi Pendidikan IPA*, 5(1), 69–78. <https://doi.org/https://doi.org/10.21831/jipi.v5i1.18707>

Bell, S. (2010). Project-based learning for the 21st century: skills for the future. *The Clearing House*, 83(2), 39–43. <https://doi.org/10.1080/00098650903505415>

Birgili, B. (2015). Creative and critical thinking skills in problem-based learning environments. *Journal of Gifted Education and Creativity*, 2(2), 71–71. <https://doi.org/10.18200/jgedc.2015214253>

Daryanto. (2014). *Pendekatan pembelajaran saintifik kurikulum 2013*. Dava Media.

De los Santos, D. M., Montes, A., Sánchez-Coronilla, A., & Navas, J. (2014). Sol-gel

application for consolidating stone: an example of project-based learning in a physical chemistry lab. *Journal of Chemical Education*, 91(9), 1481-1485. <https://dx.doi.org/10.1021/ed4008414>

Devi, S. K., Ismanto, B., & Kristin, F. (2019). Peningkatan kemandirian dan hasil belajar tematik melalui project based learning. *Jurnal Riset Teknologi Dan Inovasi Pendidikan*, 2(1), 55–65. Retrieved from <https://journal.rekarta.co.id/index.php/jartika/issue/view/24>

Ekawati, N. P. N., Dantes, N., & Marhaeni, A. A. I. N. (2019). Pengaruh model project based learning berbasis 4C membaca pemahaman pada siswa kelas IV SD gugus III Kecamatan Kediri Kabupaten Tabanan. *PENDASI: Jurnal Pendidikan Dasar Indonesia*, 3(1), 41–51. <https://doi.org/10.23887/jpdi.v3i1.2866>

Ennis, R. H. (1993). Critical thinking assessment. *Theory Into Practice*, 32(3), 179–186.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1–4. <https://doi.org/10.11648/j.ajtas.20160501.11>

Fajri, L., Martini, K. S., & S, A. N. C. (2012). Upaya Peningkatan proses dan hasil belajar kimia materi koloid melalui pembelajaran kooperatif tipe TGT (Teams Games Tournament) dilengkapi dengan teka-teki silang bagi siswa kelas XI IPA 4 SMA Negeri 2 Boyolali pada semester genap tahun ajaran 2011 / 2012. *Jurnal Pendidikan Kimia (JPK)*, 1(1), 89–96. Retrieved from <https://ejournal.undiksha.ac.id/index.php/JPK/issue>

Ferrer-vinent, I. J., Bruehl, M., Pan, D., & Jones, G. L. (2016). Introducing scientific literature to honors general chemistry students: teaching information literacy and the nature of research to first-year chemistry students. *Journal of Chemical Education*, 92(4), 617–624. <https://doi.org/10.1021/ed500472v>

Fraenkel, J., Norman, W., & Helen, H. (2011). *How to design and evaluate research in education* (8th editio). McGraw-Hill.

Hakim, M. F. Al, Sariyatun, S., & Sudiyanto, S. (2018). Constructing student`s critical thinking skill through discovery learning model and contextual teaching and learning model as solution of problems in learning history. *International Journal of Multicultural and Multireligious Understanding*, 5(4), 175. <https://doi.org/10.18415/ijmmu.v5i4.240>

Hasbie, M., Rusmansyah, & Istyadji, M. (2018). Penerapan model project based learning (PjBL) dalam pembelajaran sistem koloid untuk meningkatkan self efficacy dan kemampuan berpikir kritis peserta didik. *JCAE, Journal of Chemistry And Education*, 2(2), 50–56. Retrriewed from <http://jtam.ulm.ac.id/index.php/jcae/article/view/116/61>

Hikmah, N., Budiasih, E., & Santoso, A. (2016). Pengaruh strategi project based learning (PjBL) terhadap kemampuan berpikir kritis siswa kelas XI IPA pada materi koloid. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, 1(11), 2248–2253. Retrieved from <http://journal.um.ac.id/index.php/jptpp/>

Ismail, F. (2018). *Statistika untuk penelitian pendidikan dan ilmu-ilmu sosial*. Prenamedia Group.

Kharismawan, B., Haryani, S., & Nuswowati, M. (2018). Application of a Pbl-based modules to increase critical thinking skills and independence learning. *Journal of Innovative Science Education*, 7(1), 78–86. <https:// DOI 10.15294/JISE.V7I1.23220>

- Khiat, H. (2015). Academic performance and the practice of self- directed learning : the adult student perspective. *Journal of Further and Higher Education*, 1–16. <https://doi.org/10.1080/0309877X.2015.1062849>
- Kizkapan, O., & Bektaş, O. (2017). The effect of project based learning on seventh grade students ' academic achievement. *International Journal of Instruction*, 10(1), 37–54. Retrieved from https://www.e-iji.net/dosyalar/iji_2017_1_3.pdf
- Kurniawan, H. R., Elmunsyah, H., & Muladi. (2018). Perbandingan penerapan model pembelajaran project based learning dan think pair share berbantuan modul ajar terhadap kemandirian dan hasil belajar siswa kelas XI di SMKN 3 Malang. *Jurnal Pendiidkan*, 3(2), 80–85. <https://doi.org/http://dx.doi.org/10.26740/jp.v3n2>
- Kusadi, N. M. R., Sriartha, I. P., & Kertih, I. W. (2020). Model pembelajaran project based learning terhadap keterampilan sosial dan berpikir kreatif. *Thinking Skills and Creativity Journal*, 3(1), 18–27. <https://doi.org/10.23887/tscj.v3i1.24661>
- Loeng, S. (2020). Self-Directed Learning: A core concept in adult education. *hindawi education research International*, 2020, 1–12. <https://doi.org/https://doi.org/10.1155/2020/3816132>
- Muntari, Purwoko, A. ., Savalas, T. R. ., & Wildan. (2018). Pembelajaran berbasis proyek untuk meningkatkan keterampilan proses sains dan berpikir kritis siswa. *Jurnal Pendidikan Dan Pengabdian Masyarakat*, 1(1), 120–124. Retrieved from <https://jurnalfkip.unram.ac.id/index.php/JPPM/article/view/502>
- Nafisa, D., Sukestiyarno, S., & Hidayah, I. (2021). Critical thinking skill seen from curiosity on independent learning assisted by module. *Unnes Journal of Mathematics Education Research*, 10(2), 168–174. Retrieved from <https://journal.unnes.ac.id/sju/index.php/ujmer/issue/view/1982>
- Nahdliyati, R., Parmin, & Taufiq, M. (2016). Efektivitas pendekatan saintifik model project based learning tema ekosistem untuk menumbuhkan kemandirian belajar siswa SMP. *Unnes Science Education Journal*, 5(2), 1227–1234. <https://doi.org/10.15294/usej.v5i2.12146>
- Novianto, N. K., Masykuri, M., & Sukarmin. (2018). Pengembangan modul pembelajaran fisika berbasis proyek (project based learning) pada materi fluida statis untuk meningkatkan kreativitas belajar siswa Kelas X SMA / MA. *JURNAL INKUIRI*, 7(1), 81–92. <https://doi.org/10.20961/inkuiri.v7i1.19792>
- Puspitasari, R. D., Latifah, S., Wati, W., & Yana, E. T. (2018). Kemandirian belajar fisika pada peserta didik dengan pembelajaran berbasis proyek. *Indonesian Journal of Science and Mathematics Education*, 01(1), 1–12. <https://doi.org/10.24042/ij sme.v1i1.2461>
- Rauziani, R., Yusrizal, Y., & Nurmaliah, C. (2016). Implementasi model project based learning (PJBL) dalam meningkatkan hasil belajar dan berpikir kritis siswa pada materi fluida statis di SMA inshafuddin. *Jurnal Pendidikan Sains Indonesia*, 4(2), 39–44. Retrieved from <http://jurnal.unsyiah.ac.id/JPSI/article/view/7577>
- Reza, M., Puspita, K., & Oktaviani, C. (2021). Quantitative analysis towards higher order thinking skills of chemistry multiple choice questions for university admission. *Jurnal IPA Dan Pembelajaran IPA*, 5(2), 172–185. <https://doi.org/10.24815/jipi.v5i2.20508>
- Rumansyah, R., Yuanita, L., Ibrahim, M., Isnawati I., & Prahani, B. K. (2019). Innovative chemistry learning model:

- improving the critical thinking skill and self-efficacy of pre-service chemistry teachers. *Journal of Technology and Science Education*, 9(1), 59–76. <https://doi.org/https://doi.org/10.3926/jotse.555>
- Sagala, Y. D. A., Simanjuntak, M. P., Bukit, N., & Motlan. (2020). Penerapan project based learning berbasis LKS terhadap keterampilan berpikir kritis siswa. *Jurnal Pendidikan Fisika*, 8(2), 85–90. Retrieved from <http://digilib.unimed.ac.id/43289/>
- Saliba, R., Mussleman, P., Fernandes, M., & Bendriss, R. (2017). Promoting information literacy of pre-medical students through project-based learning: a pilot study. *International Journal of Education & Literacy Studies*, 5(4), 1–15. <https://doi.org/http://dx.doi.org/10.7575/aiac.ijels.v5n.4p.1>
- Santos, D.M.D., Montes, A., Coronilla, A.S., & Navas. J. Sol-Gel application for consolidating stone: an example of project based learning in a physical chemistry lab. *Journal of Chemical Education*, 91, 1481–1485. <https://doi.org/10.1021/ed4008414> | J. Chem. Educ. 2014, 91, 1481–1485
- Sellars, M., Fakirmohammad, R., Bui, L., Fishetti, J., Niyozov, S., Reynolds, R., Thapliyal, N., Liu-Smith, Y.-L., & Ali, N. (2018). Conversations on critical thinking: can critical thinking find its way forward as the skill set and mindset of the century? *Education Sciences*, 8(205), 1–29. <https://doi.org/10.3390/educsci8040205>
- Setiawati, H., & Corebima, A. D. (2017). Empowering critical thinking skills of the students having different academic ability in biology learning of senior high school through PQ4R - TPS strategy. *The International Journal of Social Sciences and Humanities Invention*, 4(5), 3521–3526. <https://doi.org/10.18535/ijsshi/v4i5.09>
- Sulastri, S., Rusman, R., & Arifa, A. (2018). Pengembangan soal-soal kimia bermuatan nilai-nilai untuk memperkokoh karakter siswa SMA. *JTK: Jurnal Tadris Kimiya*, 3(2), 171–181. <https://doi.org/DOI:https://doi.org/10.15575/jtk.v3i2.3512>
- Sumarni, W., Wardani, S., & Gupitasari, D. N. (2016). Project based learning (PBL) to improve psychomotoric skills: a classroom action research. *Jurnal Pendidikan IPA Indonesia*, 5(2), 157–163. <https://doi.org/10.15294/jpii.v5i2.4402>
- Suranti, N. M. Y., Gunawan, & Sahidu, H. (2016). Pengaruh model project based learning berbantuan media virtual terhadap penguasaan konsep peserta didik pada materi alat-alat optik. *Jurnal Pendidikan IPA Dan Teknologi*, 2(2), 73–79. <https://doi.org/10.29303/jpft.v2i2.292>
- Walker, M. A., & Li, Y. (2016). Improving information literacy skills through learning to use and edit wikipedia: a chemistry perspective. *Journal of Chemical Education*, 93(3), 509–515. <https://doi.org/10.1021/acs.jchemed.5b00525>
- Wardani, D. K., Martono, T., Pratomo, L. C., Rusydi, D. S., & Kusuma, D. H. (2019). Online learning in higher education to encourage critical thinking skills in the 21st century. *International Journal of Educational Research Review*, 4(2), 146–153. <http://dx.doi.org/10.24331/ijere.517973>
- Wenger, K. (2014). Problem-based learning and information literacy a natural partnership. *Pennsylvania Libraries: Research & Practice*, 2(2), 142–154. <https://doi.org/10.5195/palrap.2014.61>
- Yuliasari, E. (2017). Eksperimentasi model PBL dan model GDL terhadap kemampuan pemecahan masalah matematis ditinjau dari kemandirian belajar the effect of pbl and gdl model to mathematical problem solving ability viewed from self regulated

learning pendahuluan pendidikan adal.
JIPM (Jurnal Ilmiah Pendidikan Matematika), 6(1), 1–10.
<http://doi.org/10.25273/jipm.v6i1.1336>

Zahroh, F. (2020). Pengaruh model pembelajaran project based learning terhadap kemampuan berpikir kritis siswa pada materi elektrokimia. *Jurnal Phenomenom*, 10(2), 191–203.
<https://doi.org/10.21580/phen.2020.10.2.4283>