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Effectiveness of Assessment for Learning Instruments in Project-based Physics Learning to Measure Collaboration and Problem-Solving Skills

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ABSTRACT.
In general, the assessment model used by teachers in teaching only revolves around summative assessment, thus students cannot use it to identify the strengths and weaknesses of their skills in learning activities. This study aims to determine the effectiveness of the Assessment for Learning instrument in project-based physics learning to measure collaboration and problem-solving skills. The research design utilizes a pretest-posttest control group design. The population for this study includes all second-semester eleventh-grade science students, with the sample comprising eleventh-grade science 3 as the experimental group and eleventh-grade science 4 as the control group selected through random sampling technique. The instruments used include the Assessment for Learning learning assessment instrument and assessment to evaluate and improve students' collaboration and problem-solving activities. Data collection techniques involve observation and questionnaire collection. Data are analyzed using descriptive statistical data analysis and inferential statistics. The hypothesis testing results of collaboration and problem-solving skills indicate differences in collaboration and problem-solving skills between the experimental and control classes in project-based physics learning. It is concluded that assessment using AfL in project-based physics learning is effective in measuring collaboration and problem-solving abilities as it exceeds classical mastery.

INTRODUCTION

The state of education in Indonesia has not yielded satisfactory outcomes, as evidenced by indicators such as the 2015 PISA (Program for International Student Assessment) results score data on literacy levels, including aspects of reading, mathematics skills, and science skills, which are still at the bottom of the top 10, namely ranked 62 of the 72 member countries of the Organization for Economic Cooperation and Development (OECD) so it is necessary to apply skills that support changes in the world of education to be able to compete and improve students' learning skills, especially in the field of literacy. 21st-century skills in education consist of 6C, including critical thinking, collaboration, communication, creativity, citizenship/culture, and character education/connectivity (Miller, 2015). This 21st-century learning approach is student-centered and adapted to the 21st century learning paradigm by emphasizing that students have thinking and learning skills, including collaboration and problem-solving skills.

Collaboration skills have advantages compared to doing work individually because there is an the effective division of tasks, the integration of diverse information from multiple knowledge sources, perspectives, and experiences, as well as the enhancement of creativity and the quality of solutions through stimulation by other group members (Child & Shaw, 2016). Various empirical findings indicate that school-age children's critical thinking, problem-solving, communication, and collaboration skills are still relatively low (Ayu et al., 2018). Therefore, collaboration skills, especially in the learning process, need attention so that they become a habit for students in everyday life and academics. Apart from collaboration skills, another 21st-century skill is problem-solving skills. Problem-solving skills are fundamental skills that every student needs to have in the hope that students will become accustomed to solving or dealing with problems given by teachers with various forms of problems (Mariam et al., 2019). In physics learning, students' solving skills are still categorized as low because when students are given questions, they often directly use mathematical equations without carrying out analysis, guess the formulas used, and memorize examples of previously worked-on questions to then work on other questions (Azizah et al., 2015). Apart from that, students also experience difficulties if the physics problems they face require equation analysis so that certain equations are obtained that are appropriate to the conditions of the problem they are facing (Merisa NS et al., 2020). As a result, students become less able to solve problems and lack the skills to develop their skills (Suryani et al., 2020). So, there is a need for an assessment method or model to monitor the development of students' skills, especially collaboration and problem-solving skills.

In general, the assessment model teachers use in learning is limited to summative assessment (Khoiriah et al., 2020), so students cannot use it to determine the strengths and weaknesses of their skills in learning activities. Assessment for Learning is used during the learning process to improve students' cognitive learning outcomes and is very helpful in enhancing students' learning skills (Karimah et al., 2020). Assessment for Learning (AfL) impacts student learning outcomes and students are actively involved during the learning process to make learning activities enjoyable (Mulyana et al., 2021). The old teaching method was carried out with a monotonous learning process such as listening, taking notes, asking several questions, and discussing, and the lack of active role of students tended to result in students becoming passive learners. So, it is necessary to choose the right method or strategy in teaching so that the learning process can take place effectively and be enjoyable. The product produced is by inviting students to carry out practical activities that require students to work actively and increase students' interest in learning physics (Hamid et al., 2023).

Project-based Learning (PBL) is an instructional approach that empowers students to develop real-life skills. In PBL, students are actively engaged in the learning process, utilizing a variety of skills to solve authentic problems (Ghosheh Wahbeh et al., 2021). In project-based learning, student activities are designed to foster curiosity, leading students to explore genuine learning concepts. Additionally, students are encouraged to organize and plan their learning process, thereby fostering interest and active participation in learning activities. Collaboration is also encouraged, providing students with opportunities to think independently and collectively. This approach ensures that the acquired knowledge is not only easily remembered but also impactful and enduring (Safriana et al., 2022). The stages of the Project Based Learning learning model used in this research adopt Colley (2008) with six project-based learning cycles: orientation, identifying and defining projects, planning projects, implementing projects, documenting and reporting project findings, evaluating and taking action.

The research objectives consist of 2 objectives, to know the effectiveness of Assessment for Learning (AfL) assessment instruments in project-based physics learning to measure collaboration skills and the effectiveness of Assessment for Learning (AfL) assessment instruments in project-based physics learning in measuring problem-solving skills.

RESEARCH METHODS

Research Approach

This research design uses an experimental design with a pretest-posttest control group design. In this research design, the observed group will be given a pretest-posttest before and after being given direct treatment by applying an AfL assessment during the physics learning process using a project-based learning model by observing collaboration and problem-solving skills.

Research Participants

The population in this study were all students in 11th-grade Science, even the 2022/2023 academic year semester at the school where the research took place, namely, Public Senior High School 15 Bandar Lampung. The total population is four classes, with each class having 35 students. Sampling from the population used a simple random sampling technique, where the sample was determined based on the advice of the study teacher and according to the needs of the researcher, namely two classes from the existing population with division into one experimental class, namely 11th-grade Science 3 and one control class, namely 11th grade Science 4.

Research Instruments

The research instruments used in this research are as follows.

1. Teacher Questionnaire Instrument

This instrument is used when conducting preliminary studies to obtain initial information, which is the focus of the problems raised in this research. The instruments were given to physics teachers at the Senior High School, which was used as the research location. The aspects analyzed from this questionnaire are: (1) learning process and assessment; (2) assessment of students' collaboration skills; (3) assessment of students' problem-solving skills; (4) the need for instrument implementation. This instrument consists of 26 statement items with four scales provided, namely always, often, sometimes, and never, and for the statement of instrument implementation using a scale of strongly agree, agree, disagree, and strongly disagree.

2. Indicators of Assessment Instrument

Assessment instruments include an instrument for assessing student collaboration skills adapted from (Franker, 2018) and an instrument for assessing problem-solving skills adapted from (Diawati, 2018), which has been validated. The following are the instrument indicators used, namely:

a. Collaboration Skills Assessment Instrument

This instrument consists of 11 aspects of collaborative observation, as shown in Table 1.

Table 1. Aspects of observing students' collaboration skills

No.	**Collaboration Aspect**	**Observation Aspect**	**Score**			
			3	**2**	**1**	**0**
(1)	**(2)**	**(3)**	**(4)**			
1.	Focus on tasks and participation.	1. Students focus on the task and do the part that needs to be done yourself. 2. Students provide ideas and efforts within the group and provide encouragement and support for the efforts of others in the group.				
2.	Dependency between members and responsibilities	3. Students discuss and complete group work on time. 4. Students could follow up on assigned tasks, not depend on others when carrying out tasks, and be responsible for tasks that are distributed equally.				
3	Listen, ask questions, and discuss	5. Students can listen, interact, discuss, and ask questions well to fellow group members during discussions and help the group achieve project goals.				
4.	Find out and share information.	6. Students collect reference information and share and develop ideas that can be useful when participating in group discussions to achieve project goals.				
5.	Solution to problem	7. Students actively seek and suggest solutions to problems in the group.				
6.	Teamwork	8. Students can work together to make the necessary agreements within the group to achieve project goals. 9. Students have a positive attitude towards other people's tasks and work 10. Students make equal contributions to the project by completing group assignments 11. Students always carry out their assigned roles in the group and				

No.	Collaboration Aspect	Observation Aspect	Score			
			3	2	1	0
(1)	(2)	(3)	(4)			
		provide knowledge, opinions, and skills that are shared within the group				

(Franker, 2018)

This instrument is used to measure students' collaboration skills in the experimental class during the learning process in project-based physics learning (Assessment for Learning), and to measure students' collaboration skills in the control class after the end of the learning process (Assessment of Learning).

b. Problem-Solving Skills Assessment Instrument

This instrument consists of 5 items on the problem-solving skills aspect, which are then divided into 11 observation aspects as in Table 2

Table 2. Aspects of observing problem-solving skills

No.	Problem-Solving Aspects	Observation Aspect	Score			
			4	3	2	1
(1)	(2)	(3)	(4)			
1.	Contribute to formulating project problems and ideas	1. Students can write relevant and varied problem formulations 2. Students can write a formulation of an idea relevant to the project objectives				
2.	Actively discuss project design.	3. Students can describe tool modification procedures, correct concepts, and relevant ones. 4. Students can detail a list of materials and tools in appropriate quantities and adequate and relevant materials. 5. Students can draw equipment designs using concepts correctly.				
3	Understand the function and principles of the tool	6. Students can explain the function of each tool component 7. Students can explain the working principles of each tool component 8. Student capable explains the principle of operation of the tool in the design				
4.	Work together to assemble tools creatively.	9. Students capable of assembling tools in a compact and attractive way				
5.	Skills to solve problems by testing tools and evaluating work	10. Student capable test to prove that the tool can work 11. Students can test to prove that tool design is easy to do				

(Diawati et al., 2018)

This instrument measures students' problem-solving skills in the experimental class during the learning process in project-based physics learning (Assessment for Learning) and students' problem-solving skills in the control class after the learning process (Assessment of Learning).

Data Collection

The data collection technique in this research uses quantitative descriptive methods. Descriptive, namely by conducting observations at the research location school and teacher questionnaires collected to obtain information, then the researcher explains the situation under study. Meanwhile, quantitative analysis is used to measure data using research instruments. The questionnaire used to collect information was a teacher questionnaire that was submitted when conducting a preliminary study.

This teacher questionnaire consists of 26 statement items with four scale options for 24 statements, namely: (1) very often, (2) often, (3) sometimes, and (4) never. Meanwhile, two other statements regarding the implementation of the instruments studied used four scales, namely: (1) strongly agree, (2) agree, (3) disagree, and (4) strongly disagree. Observations of students were carried out using an Assessment for Learning (AfL) instrument for the experimental class and an assessment of learning (AoL) for the control class. This assessment instrument has a special function: measuring students' collaboration and problem-solving skills during treatment using PjBL.

The assessment indicator items contained in the instrument for collaboration skills are composed of 6 items. They are divided into 11 aspects of observation, while problem-solving skills comprise 5 aspects of assessment and are divided into 11 observation aspect items with assessment option categories that can be translated, and this instrument has been validated.

Data Analysis

This research uses two data analysis techniques: descriptive statistical data analysis and inferential statistics. Descriptive statistical analysis describes or depicts data obtained by researchers in the field. In contrast, inferential analysis is a form of quantitative data analysis that analyzes the sample data obtained and then draws conclusions through statistical formulas.

1. Descriptive Statistical Data Analysis

Descriptive statistical data analysis determines the data's characteristics, including calculating the average value, median, variant value, lowest value, and highest value. This analysis was carried out to determine classical completeness and individual completeness from the experimental class. The teaching and learning process is effective if ≥ 85%students have completed the specified individual learning mastery in the class. Learning completion is adjusted to the school where the research occurred, namely 15 Senior High School Bandar Lampung, with an individual completion score of 75.00. The percentage of classical completeness can be calculated using the following formula.

$$P = \frac{\Sigma Total\ of\ students\ complete}{\Sigma Total\ of\ students} \times 100\%$$

Information:
P = Percentage of classical completion

2. Inferential Statistical Data Analysis

a. Kolmogorov-Smirnov Normality Test

The principle of the Kolmogorov-Smirnov test is to compare the normal distribution of the data to be tested with the standard normal distribution so that it is known whether the data is normally distributed. The Kolmogorov-Smirnov test was carried out using SPSS 26.0 software. The basis for drawing conclusions can be done by comparing *Asymp. Sig.* or significance with the commonly used significance level, namely $\alpha = 0,05$. The guidelines for concluding this test are in Table 5.

Table 3. Normality test criteria

Criteria	Description	Interpretation
$\alpha \leq 0,05$	Asymp. Sig. or significance less or equal to 0.05	Data is not normally distributed
$\alpha > 0,05$	Asymp. Sig. or significance more than 0.05	Data is normally distributed

(Nasrum, 2018)

b. Homogeneity Test

The homogeneity test in this study used IBM SPSS 26.0 software. Suppose the data test results obtained are homogeneous. In that case, the data can be subjected to parametric statistical hypothesis testing. Still, if the data obtained is not homogeneous, parametric tests cannot be carried out but non-parametric tests. The homogeneity test results can be interpreted by looking at the following significance values.

a) If the sig value. $< 0{,}05$, then it is said that the variants of two or more population groups are not homogeneous.
b) If the sig value. $\geq 0{,}05$, then it is said that the variants of two or more population groups are not homogeneous.

c. N-Gain Score Test

The normalized gain test (N-Gain) is conducted to assess the improvement in students' cognitive learning outcomes following treatment. This improvement is measured by comparing the pretest and posttest scores obtained by students. N-Gain is calculated by comparing the actual gain score, which is the difference between pretest and posttest scores, with the maximum possible gain score that a student can achieve. The research results were tested using normalized gain values, namely the comparison between the actual average growth and the maximum possible average growth, namely with the formula (Sugiyono, 2014).

$$N - Gain = \frac{Post\ test\ score - Pre\ test\ score}{100 - Pre\ Test\ score}$$

The N-Gain value criteria with progress categories are as follows:

Table 4. N-Gain score category

N-Gain Score	**Category**
$N - Gain \geq 0{,}70$	High
$0{,}70 > N - Gain > 0{,}3$	Medium
$N - Gain \leq 0{,}3$	Low

The categories for obtaining an interpretation of Ngain's effectiveness in percent are stated as follows in Table 5.

Table 5. Categories of interpretation of N-Gain effectiveness (%)

Percentage (%)	**Interpretation**
< 40	Ineffective
40 – 55	Less effective
56 – 75	Effective enough
> 76	Effective

d. Independent Sample T-Test

The independent sample t-test is a comparative test or difference test to determine whether there is a significant difference in the mean between two independent groups. The two independent groups in question are unpaired or the data sources come from two subjects. Decision-making from Independent Sample T-test data testing, namely:

a) If sig. > 0.05 then H_0 is accepted and H_1 is rejected
b) If sig. < 0.05 then H_0 is rejected and H_1 is accepted

3. Hypothesis test

Hypothesis testing is carried out through the Independent Sample T-Test if the data being tested is normally distributed and homogeneous. This test aims to prove that there is a difference in the average score of collaboration and problem-solving skills of students who are given certain treatment. This test will be carried out using IBM SPSS 26.0 software. The hypothesis that will be tested is as follows.

1) Variable hypothesis Y_1 (collaboration skills students)

H_0 : There is no difference in students' collaboration skills in experimental classes that use the Assessment for Learning (AfL) instrument and classes that use Assessment of Learning (AoL) for project-based physical learning.

H_1: There is a difference in students' collaboration skills in experimental classes that use the Assessment for Learning (AfL) instrument and classes that use Assessment of Learning (AoL) for project-based physical learning.

2) Variable hypothesis Y_2 (problem-solving skills students)

H_0: There is no difference in students' collaboration skills in experimental classes that use the Assessment for Learning (AfL) instrument and classes that use Assessment of Learning (AoL) for project-based physical learning.

H_1: There is a difference in students' collaboration skills in experimental classes that use the Assessment for Learning (AfL) instrument and classes that use Assessment of Learning (AoL) for project-based physical learning.

According to (Reni et al., 2021), decision-making criteria are based on skills values for a two-sided test, namely:

a) If the sig value. or significance $< 0{,}05$ then H_0 is rejected and H_1 is accepted.

b) If the sig value. or significance $\geq 0{,}05$ then H_0 is accepted and H_1 is rejected.

RESULTS AND DISCUSSION

Results Data

1) Descriptive Data Results

This research uses non-test techniques, namely by observation. The following is a descriptive data analysis of the research results, which can be seen in Table 6 and Table 7.

Table 6. Descriptive data of collaboration skills results

Parameter	Experimental Class	Control Class
Average	81.12	75.14
Median	81.8	75.00
Variance	91.85	78.66
Std. Deviation	9.58	8.87
Lowest Value	54.54	60.00
The highest score	100.00	90.00

Table 6 shows that the average collaboration skills score for the experimental class is greater than the average result for the control class. Meanwhile, the standard deviation of the experimental class is greater than that of the control class.

Table 7. Descriptive data of problem solving skills results

Parameter	Experimental Class	Control Class
Average	80.32	73.93
Median	79.54	75.00
Variance	53.14	86.13
Std. Deviation	7.29	9.28
Lowest Value	59.09	56.25
The highest score	97.73	93.75

Table 10 shows that the average results of the assessment of problem-solving skills in the experimental class are greater than those in the control class. Meanwhile, the standard deviation of the experimental class is smaller than that of the control class.

2) Normality Test Results
The normality test results for experimental and control class data can be seen in Table 8 and Table 9.

Table 8. Collaboration skills normality test results

Class	Sig.	Information
Experiment	0.055	Normally distributed
Control	0.052	Normally distributed

Table 8 shows that the collaboration skills scores in the experimental and control classes are normally distributed, where the Sig. of the experimental class and control class have a value of $> 0{,}05$. Both data meet the requirements for the Independent Sample T-Test.

Table 9 . Normality test results for problem solving skills

Class	Sig.	Information
Experiment	0.200	Normally distributed
Control	0.057	Normally distributed

Table 9 shows that the normality test scores for problem solving skills in the experimental and control classes are normally distributed, where the Sig. $> 0{,}05$. Both data meet the requirements for the Independent Sample T-test.

3) Homogeneity Test Results
The homogeneity test results on the students' collaboration skills scores can be seen in Table 10 and problem-solving skills in Table 11.

Table 10. Collaboration skills homogeneity test results

Levene Statistics	df1	df2	Sig.	Interpretation
0.095	1	68	0.759	Homogeneous

In Table 10, the Sig value is shown. The homogeneity test results in the experimental class and control class $> 0{,}05$ were 0.759, so it can be said that the data is homogeneous. The Independent Sample T-Test can be carried out because the data is normally distributed and homogeneous.

Table 11. Results of the homogeneity test for problem solving skills

Levene Statistics	df1	df2	Sig.	Interpretation
3,072	1	68	0.084	Homogeneous

Table 11 shows that the Sig. The results of the homogeneity test of problem-solving skills in the experimental and control classes $> 0{,}05$ were 0.084, so it can be said that the data is homogeneous. The Independent Sample T-test can be carried out because the data is normally distributed and homogeneous.

4) Hypothesis Test Results
Test results can be seen in Table 12.

Table 12. Independent sample t-test results for collaboration skills

Class	N	Mean	S.D	T	Sig (2-tailed)	Interpretation
Experiment	35	81.1166	9.58378	2,707	0.009	There is a difference.
Control	35	75.1429	8.86879			

Table 12 shows the results of the Independent Sample T-test Sig value. (2-tailed) $< 0{,}05$ then H_0 is rejected and H_1 is accepted. Decision-making means that there are differences in students' collaboration skills in the experimental class, which uses the AfL instrument, and in the control class, which uses AoL for project-based physics learning.

Table 13. Independent sample t-test results for problem-solving skills

Class	N	Mean	S.D	Q	Sig (2-tailed)	Interpretation
Experiment	35	80.3211	7.29001	3,205	0.002	There is a difference.
Control	35	73.9286	9.28086			

Table 13 shows the results of the Independent Sample T-test Sig value. (2-tailed) < 0,05 then H_0 is rejected and H_1 is accepted. Decision making means that there are differences in students' problem-solving skills in the experimental class, which uses the AfL instrument, and in the control class, which uses AoL for project-based physics learning.

5) N-Gain Test Results

The N-Gain test results were carried out on the Pre-test and Post-test results using SPSS 26.0 software. This test was carried out to determine the increase in students' cognitive learning outcomes after being given treatment. Data from the N-Gain test results can be seen in Table 14.

Table 14. Pretest and posttest n-gain test results

Class	Mean Pre-test	Mean Post-test	Mean N-gain	Maks. N-gain	Min. N-gain	Interpretation
Experiment	54,51	86,23	70.20	93.94	59.62	Effective enough
Control	51,1	74,31	45.56	62.69	13.51	Less effective

Table 14 shows that the average N-Gain in the experimental class is 70.20%, categorized as high and declared quite effective according to the category of N-Gain effectiveness interpretation, while in the control class, the average N-Gain value is 45.56%. Moderate category and interpreted as less effective.

The average N-Gain data is interpreted to mean that learning activities using assessment for learning have a quite effective impact compared to assessment of learning, which is less effective. Project-based learning and assessment systems during the learning process impact measurable student learning outcomes and increase students' problem-solving skills.

Class Classical Completeness Result

Class Classical Completeness can be seen in Table 15

Table 15. Class classical completeness

Skills	Class	The number of students	The complete number of students	The number of students is incomplete	Classical completeness
Collaboration	Experiment	35	30	5	85.71%
	Control	35	19	16	54.29%
Solution to problem	Experiment	35	32	3	91.43%
	Control	35	21	14	60%

Table 15 shows the classical completion of the collaboration and problem-solving skills scores of students in the experimental and control classes. The experimental class obtained collaboration and problem-solving skills scores that exceeded classical completeness, where in collaboration, 30 out of 35 students completed the score with a percentage of 85.71% and 32 out of 35 students completed the problem-solving skills with a percentage of 91.43%.

Discussion

1) Collaboration Skills

During the project-based physics learning process, observations were made of the learning outcomes of students' collaboration skills,,andwere ationresearch resultsts show that classical completeness in the application of assessment using the AfL instrument in the experimental class has exceeded the minimum classical learning criteria, namely 85%. So it can be said that the At is considered effectivinilearningearning. This result is in line with the research results of Oyinloye & Imenda (2019), which state, which state that the application of AfL in teaching and learning activities is considered effective. The achievement of classical completion of students' collaboration skills can be seen in Figure 1 below.

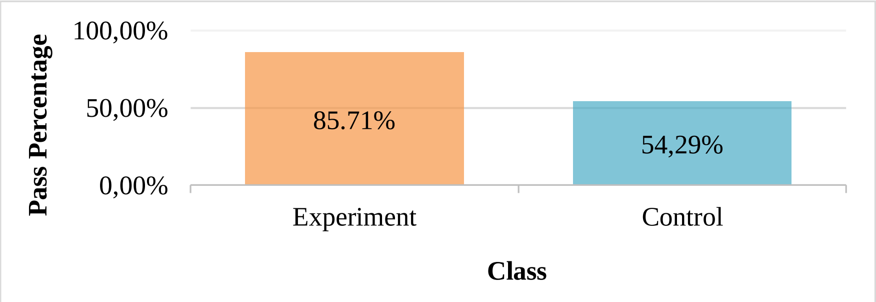

Figure 1. Achievement of classical completion of collaboration skills

Figure 1 shows that classical completeness in the collaboration skills of the experimental class has far exceeded the minimum completeness and is more significant than classical completeness in the control class. This difference can occur because during the learning process, AfL places more emphasis on the use of feedback in learning activities used by students to find out the potential of each student in facing their learning. Supported by Mumpuni & Ramli (2018), who stated that feedback in assessment activities is essential because students and teachers can use it to improve the quality of learning.

The results of the hypothesis test on students' collaboration skills through the Independent Sample T-test show a value of Sig. (2-tailed) is 0.009 < 0,05, then H_o is rejected and H_1 is accepted. Decision-making based on these values shows that there are differences in students' collaboration skills between classes that use the AfL instrument and classes that use the AoL instrument when learning project-based physics. Integrating project-based physics learning methods with AfL will make the assessment process of collaboration skills more effective. This is supported by Setiawati et al. (2019), who stated that forms of formative assessment, including presentation assignments, projects, and quizzes, are a form of assessment for the learning process.

The collaboration skills assessment consists of 11 sub-indicators with varying assessment results indicating various levels of student skills. The AfL assessment results for each experimental class sub-indicator can be seen in Figure 2 below.

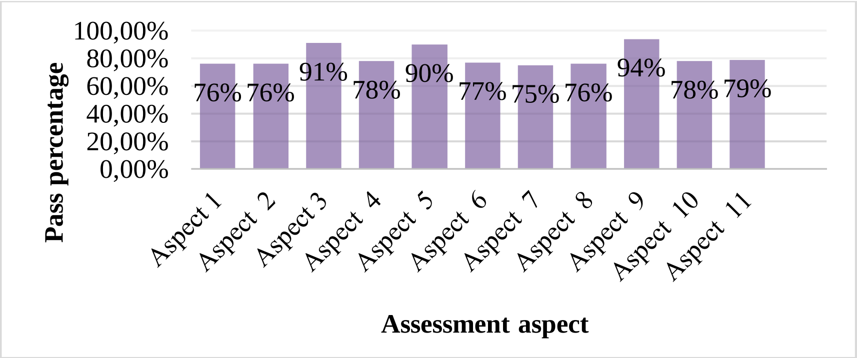

Figure 2. Percentage graph of collaboration AfL assessment results

Figure 2 shows the percentage of AfL assessment results on experimental class collaboration skills. It can be seen that the average collaboration skills of students is highest in assessment sub-indicator number 9, namely 94%, which means that 94% of students have a positive attitude about assignments and work. Other people, while the lowest percentage is the assessment in the 7th sub-indicator of 75%, which means that 75% of students are actively looking for and suggesting solutions to problems. The percentage produced in the AfL results is relatively large, which proves that there is good collaboration in the experimental class, in line with research by Care et al. (2016), which states that paying attention to perspectives and respecting other people's understanding can create better team coordination between members.

The AoL collaboration skills assessment consists of 5 indicators with varying assessment results indicating various levels of student skills. The AoL assessment results for each experimental class sub-indicator can be seen in Figure 3 below.

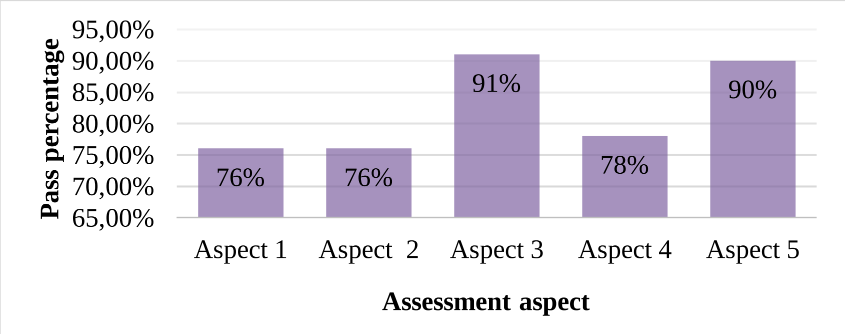

Figure 3. Percentage Graph of Collaboration AoL Assessment Results

Figure 3 shows the results of the AoL assessment for collaboration skills in the control class. It can be seen that the highest average collaboration skills of students is in assessment sub-indicator number 4, namely 89% with the assessment of students listening to opinions and helping others, while the lowest percentage is assessment in sub-indicator number 5 it was 57% with assessment of students looking for various sources and recording information.

2) Problem-Solving Skills

Observations of problem-solving skills were carried out simultaneously with collaborative observations, that is, during the learning process, the results were analyzed descriptively. The research results show that classical completeness in the use of the AfL instrument in the experimental class has exceeded the minimum criteria for classical learning completeness. The achievement of classical completeness in problem-solving skills can be seen in Figure 5.

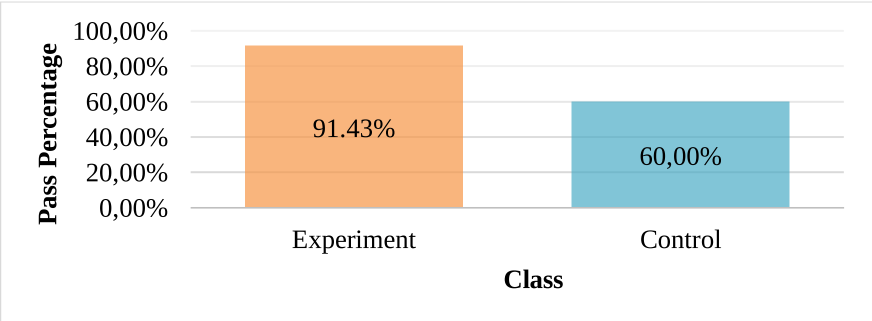

Figure 4. Achievement of classical completion of problem-solving skills

Figure 4 shows that classical completeness in the problem-solving skills of the experimental class exceeds the minimum completeness and is greater than classical completeness in the control class. This difference occurs because, during the learning process, AfL places greater emphasis on the use of feedback and is directed at being able to solve the problems faced by gaining new understandings through searching for information and discussions to come up with solutions in the learning activities used by students so that they can find out their potential in facing learning in line with Purnamasari & Setiawan (2019), who stated that problem-solving is the first step for students to develop new ideas in building new knowledge and developing new mathematical skills. Such a process can stimulate students to find solutions from various points of view.

The hypothesis test results on students' problem-solving skills carried out through the Independent Sample T-test showed Sig. (2-tailed) is 0.002 < 0,05, then H_0 is rejected and H_1 is accepted. Decision-making based on these values shows differences in students' problem-solving skills between classes that use the AfL instrument and classes that use the AoL instrument when learning project-based physics.

The assessment of problem-solving skills consists of 11 assessment sub-indicators with assessment results showing various levels of students' skills. The AfL and AoL assessment results for each experimental class sub-indicator can be seen in Figure 5.

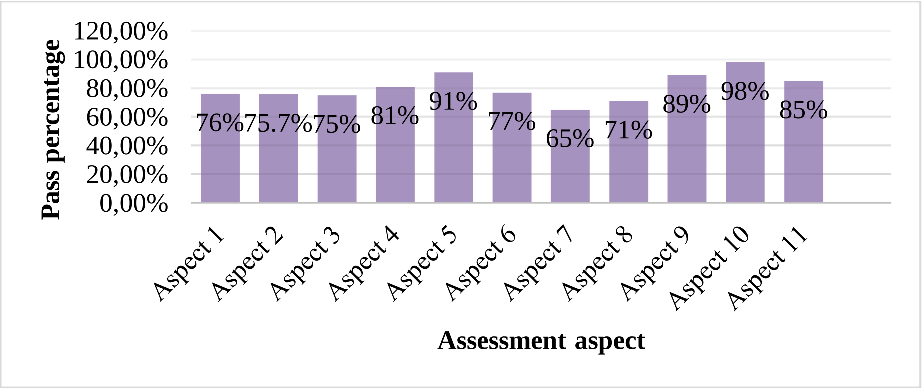

Figure 5. Percentage graph of problem solving AfL assessment results

Figure 5 shows the percentage of AfL assessment results on experimental class problem-solving skills. It can be seen that the average problem solving skills of students is highest in assessment sub-indicator number 10, namely 98%, which means that 98% of students are able to test to prove that the tool can function, while the lowest percentage was the assessment in the 7 sub-indicator of 65%, which means that 65% of students were able to explain the working principles of each tool component.

The use of AfL to measure problem solving skills is considered effective, as can be seen in Figure 5 which shows the percentage of each observation indicator which is quite good overall. This assertion is consistent with the findings of Makrufi et al. (2018), who argue that the enhancement of students' problem-solving skills is intricately linked to the various stages of the project-based learning model. By incorporating projects into the learning process, students are encouraged to engage in reflective thinking. Moreover, project-based learning mandates the utilization of all senses by students to explore concepts, under the guidance of teachers who facilitate active involvement throughout the learning stages. The direct engagement of students in constructing concepts leads to a deeper understanding and mastery of the concepts.

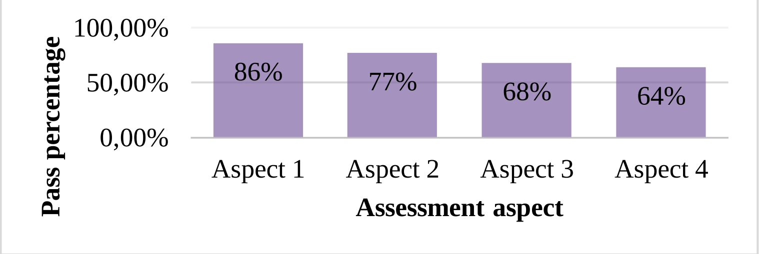

Figure 6. Percentage graph of AoL problem solving assessment results

Figure 6 shows the results of the AoL assessment for problem-solving skills in the control class. It can be seen that the average problem-solving skills of students is highest in assessment sub-indicator number 1, namely 86%, with the assessment of students being able to understand the problem by identifying the variables asked completely. While the lowest percentage is the assessment in sub-indicator number 4 of 64% with students' assessment of checking the answers and correctness of the concept.

The results of this research show that using AfL in learning in experimental classes is more effective because students receive direction in the learning stages and feel that every activity carried out will be assessed with assessment points that must be met to achieve satisfactory results in learning. This is in line with research conducted by Oyinloye and Imenda (2019), which shows that assessment for learning is effective in teaching and learning activities. Students' active involvement in learning significantly influences student learning outcomes. This is corroborated by Mulyana et al. (2021), who assert that the implementation of Assessment for Learning (AfL) not only enhances student learning outcomes but also fosters a sense of engagement among students throughout the learning process, thereby making learning activities more enjoyable.

CONCLUSION

Using the Assessment for Learning (AfL) instrument in project-based physics learning effectively measures students' collaboration and problem-solving skills. The results of the hypothesis test show differences in students' collaboration and problem-solving skills between the experimental class and the control class, which can be seen through the Sig (2-tailed) value with a value of <0.05. Classical completion in the experimental class was 85.71%, while problem-solving reached 91.43%.

Teachers should use AfL to measure students' collaboration and problem-solving skills in physics learning so that assessments can be more effective. The use of AfL can be integrated with learning methods, one of which is the project-based learning method. This is because at each stage of the project-based learning method, students are required to be more active in collaborating and problem-solving when compiling, planning, and implementing projects. So that every learning activity can be monitored well and teachers can carry out assessments more easily and effectively through AfL. The weakness of this research is that when researchers carry out the assessment process manually, it would be better if the assessment was carried out digitally because it makes it easier for teachers to carry out the assessment process themselves.

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References

Ayu, P. S., Marhaeni, A. A. I. N., & Budiadnyana, P. (2018). Pengembangan instrumen asesmen keterampilan belajar dan berinovasi pada mata pelajaran IPA SD. *PENDASI: Jurnal Pendidikan Dasar Indonesia, 2*(2), 90-100. https://doi.org/10.23887/jpdi.v2i2.2696

Azizah, R., Yuliati, L, & Lathifah, E. (2015). Pemecahan Masalah Fisika pada Siswa SMA. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA), 5*(2). 44-50.

Care, E., Scoular, C., & Griffin, P. (2016). Assessment of collaborative problem solving in education environments. *Applied Measurement in Education, 29*(4), 250-264. https://doi.org/10.1080/08957347.2016.1209204

Child, S. & Shaw, S. (2016). Kolaborasi Di Abad 21: Implikasinya untuk penilaian. *Jurnal UCLES, (22)*, 17-22.

Colley, K. (2008). Project-based science instruction: A primer. *The Science Teacher, 75*(8), 23.

Diawati, C., Liliasari, Setiabudi, A., & Buchari. (2018). Using project-based learning to design, build, and test student-made photometer by measuring the unknown concentration of colored substances. *Journal of Chemical Education, 95*(3), 468-475. DOI: 10.1021/acs.jchemed.7b00254

Franker, Dr. K. (2018). Collaboration Rubric for Examples of Other Rubrics. Wisconsin University: Rubric A+. https://www2.uwstout.edu/

Hamid, A., Mardiah, A., Wahyuni, A., Kasli, E., Wahyuni, S., Ngadimin, N., & Zainuddin, Z. (2023). Development of a Laboratory-based Physics Module with a Science Process Skills Approach to enhance the interest of High School Students. *Asian Journal of Science Education*, *5*(1), 1-10.

Karimah, H. N., Windyariani, S., & Aliyah, H. (2020). Penggunaan Assesment For Learning Berbasis Comment Only Marking Terhadap Hasil Belajar Kognitif Siswa:(Use of Comment Only Marking Based Assessment for Learning on Student Cognitive Learning Outcomes). *BIODIK, 6*(3), 255-265.. https://doi.org/10.22437/bio.v6i3.9578

Khoiriah, K., Jalmo, T., & Abdurrahman, A. (2020). Implementasi assessment for learning berbasis higher-order thinking skills untuk menumbuhkan minat baca. *Jurnal Inovasi Pendidikan IPA, 6*(2), 176-183.

Makrufi, A., Hidayat, A., & Muhardjito, M. (2018). Pengaruh model pembelajaran berbasis proyek terhadap kemampuan pemecahan masalah pokok bahasan fluida dinamis. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan, 3*(7), 878-881. https://doi.org/10.17977/jptpp.v3i7.11291

Mariam, S., Nurmala, N., Nurdianti, D., Rustyani, N., Desi, A., & Hidayat, W. (2019). Analisis kemampuan pemecahan masalah matematis siswa mtsn dengan menggunakan metode open ended di Bandung Barat. *Jurnal Cendekia: Jurnal Pendidikan Matematika, 3*(1), 178-186.

Merisa, N. S., Halim, A., & Mahzum, E. (2020). The Effects of Exercise Using Minnesota Strategy Problem Solving Model to Student Learning Outcomes and Critical Thinking Ability. *Asian Journal of Science Education*, *2*(1), 24-32.

Miller, BS (2015). Pendidikan versi 6Cs kuadrat di abad ke-21. www.bamradionetwork.com. Diakses pada 26 Juli 2018.

Mulyana, T., Kurniasih, S., & Ardianto, D. (2021). Assessment for learning: changes in the role of assessment in learning. *IJORER: International Journal of Recent Educational Research*, *2*(5), 580-589. https://doi.org/10.46245/ijorer.v2i5.146

Mumpuni, KE, & Ramli, M. (2018). Penerimaan dan Pengetahuan Mahasiswa tentang Assessment for Learning. *BIOEDUKASI: Jurnal Pendidikan Biologi*, *11*(1), 55-60.

Nasrum. (2018). *Uji Normalitas Data untuk Penelitian*. Kota Denpasar: Jayapangus Press.

Oyinloye, O.M., & Imenda, S.N (2019). The Impact of Assessmentfor Learning on Learner Performance in Life Science. *EURASIA Journal of Mathematics, Science and Technology Education*, *15*(11), 1-8. https://doi.org/10.29333/ejmste/108689

Purnamasari, I., & Setiawan, W. (2019). Analisis kemampuan pemecahan masalah matematis siswa SMP pada materi SPLDV ditinjau dari kemampuan awal matematika. *Journal of Medives: Journal of Mathematics Education IKIP Veteran Semarang*, *3*(2), 207-215.

Reni, SA, Praherdhiono, H., & Soepriyanto, Y. (2021). Peningkatan Keterampilan Kolaborasi Desain Menggunakan Model Kooperatif Tipe STAD Secara Online. *JKTP: Jurnal Kajian Teknologi Pendidikan, 4*(3), 270-279.https://doi.org/10.17977/um038v4i32021p270

Safriana, S., Nurlina, N., Ginting, F. W., & Badriah, B. (2022). The Use of Project Based Learning to Improve Students' Concept Understanding on Elasticity and Hooke Law. *Asian Journal of Science Education, 4*(1), 1-8.

Setiawati, W., Asmira, O., Ariyana, Y., Bestary, R., & Pudjiastuti, A. (2019). *Buku Penilaian Berorientasi Higher Order Thinking Skills*. Jakarta: Kementerian Pendidikan dan Kebudayaan.

Sugiyono. 2014. *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta

Suryani, M., Jufri, LH, & Putri, TA (2020). Analisis Kemampuan Pemecahan Masalah SiswaBerdasarkan Kemampuan Awal. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(1), 119–130.

Ghosheh Wahbeh, D., Najjar, E. A., Sartawi, A. F., Abuzant, M., & Daher, W. (2021). The role of project-based language learning in developing students' life skills. Sustainability, 13(12), 6518..https://doi.org/10.3390/su13126518