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Learning Analytics Approach to Improve Multiple Representation Skills in Direct-Current Circuits

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ABSTRACT

A high failure rate in physics subjects is caused by students' inability to understand the material. The physics learning process certainly requires an appropriate learning approach. The learning analytics approach is one of the innovations in learning. It allows students to analyze problems. Therefore, this research aimed to determine the learning analytics approach's effect on improving students' multiple representation skills. This research is experimental. The validation of the lesson plan obtained excellent results based on two material experts and four practitioners. Furthermore, the empirical test was carried out on 504 students. The research design was the pretest-posttest control group design. The control and experimental groups were determined using cluster random sampling. The findings of this research include (1) the normality test results that are higher than 0.05, which means that the research data was normally distributed. (2) The homogeneity test results were higher than 0.05, which indicated that the data was homogeneous. (3) The paired sample T-test obtained a value lower than 0.05, which means that there was an influence of the multiple representation approach. (4) The N-gain value in the experimental class was higher than the control class. Lastly, (5) only 47.2% of students used graphical and mathematical representation skills. Based on these findings, the effect of the learning analytics approach on students' multiple representation skills was fairly good with moderate criteria. For further research, learning products or models can be developed to improve multiple representation skills focused on a combination of graphics and mathematics.

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INTRODUCTION

Education has an important role in improving human resources. Education gives humans optimal potential (Hermino & Arifin, 2020). Education obtained with the right learning models and methods will positively impact students. The choice of learning model must be adjusted to the characteristics of students (Darihastining et al., 2021). Physics is one of the materials studied in high school. Learning physics has its level of difficulty (Fidan & Tuncel, 2019). The main sources of difficulty in learning physics include the nature of the subject, teaching factors, and assessment. Physics subjects are considered difficult due to the many equations and problems students must solve. Teaching factors in learning physics greatly affect learning outcomes. This teaching includes lesson plans, media, and ways of delivering materials. Assessment is also a difficulty in learning physics because students have to work on questions at a high level of thinking. Physics subjects require students to understand mathematical visualization (Sarabi & Gafoor, 2018). The high failure rate in physics is due to students' inability to understand the material's content and the basic principles.

One of the physics materials is direct-current circuits. This material requires an abstract understanding and has a high level of difficulty (Susdarwati et al., 2021; Yuliati et al., 2018), especially in Kirchhoff's Law

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material with a difficulty percentage reaching 71.42% (Sari et al., 2019). Direct current is abstract because students cannot directly see the flow of electrons or electricity in a circuit. Therefore, there is a need for innovation in learning.

Learning at school requires an appropriate learning approach. In recent years, the evolution of educational research has focused on Learning Analytics (LA) (Ranjeeth et al., 2020). This approach allows analyzing, informing, and improving learning activities (Lawson et al., 2016). An effective LA design can implement integrated analytics with pedagogy and technology (Buckingham Shum & Deakin Crick, 2016). In addition, LA assists students in collecting, analyzing, managing, and presenting data (Adejo & Connolly, 2017). This learning approach allows students to analyze data obtained from the practical results of direct-current circuits. However, the LA concept is rarely used in teaching practice. There are 26% categorized as 'theory users' and only 11% as 'developing theory' (Viberg et al., 2018). LA, as a new form of learning approach, has the potential to support current educational practices. With the innovation of different learning approaches, it is hoped that students can be motivated to learn, especially in direct-current circuits.

The learning process with LA shows students' skills to make decisions and actions based on that information. The LA stage was adopted from Elias (2011). They consist of seven stages: select, capture, aggregate & report, predict, use, refine, and share. However, this learning approach can also be adopted for senior high school students, as an effort to acquaint them with analytical processes. The seven stages are shown in Table 1.

Table 1. Synthesis of Stages and Indicators in Learning Analytics

Stage	Indicator
Select	• Determine the type of practicum that each group will carry out. • Define practical goals.
Capture	• Searching for literature from various media, books, or related articles.
Aggregate and report	• Combine the two and report progress to the teacher.
Predict	• Put forward a hypothesis before doing a practicum.
Use	• Using literature in conducting practicum.
Refine	• Consultation to get practical results with small errors. • The practicum stage must be repeated if there is an error.
Share	• Presenting practical results in front of the class.

Students must improve their thinking skills. Representation skills are the interpretation of students' thoughts on a problem. In learning physics, not only one representation is needed. It might include images, graphics, and mathematics (Nuha et al., 2021). The combination of several representations is called multiple representation. Multiple representation can be defined as a way to represent the same concept in different formats (Masrifah et al., 2020). Through multiple representations, the same concept can be explained by different types of representation modes (Mainali, 2021). Multiple representations, such as physics, are needed in conceptual learning (Altmeyer et al., 2020). Students must be trained to develop multiple representation skills (Prahani et al., 2017) because multiple representations emphasize understanding concepts and qualitative reasoning in learning. Multiple representations can be used to encourage students to build in-depth understanding (Lahore et al., 2020). Another reason to use representations in learning physics is because of the structure of physics itself (Airey et al., 2017). The structure of physics includes mathematical calculations and conceptual understanding of problems in everyday life. The structure causes difficulties in learning physics. Difficulties in learning physics are caused by various things simultaneously in learning (Liliarti & Kuswanto, 2018). In physics, the students are expected to master problems and solve them with correct analysis. Therefore, they need to develop representational skills. In physics learning, more than one representation format or multiple representations are needed to convey information and knowledge construction.

Therefore, innovation in physics learning is needed. LA approach is one solution so that students are more active in learning. It can improve learning outcomes for learning management systems at a university in Hong Kong (Foung & Chen, 2019). In addition, students who use the learning analytics approach in their learning can improve cognitive abilities and learning achievement (Sun et al., 2022). However, the learning analytics approach has not been implemented in high schools. The stages in learning analytics are oriented toward the activeness and the student's way of thinking. In addition, with the learning analytics approach, students are expected to be able to improve their analytical skills so that multiple representation skills can be increased. Thus, this study aimed to determine the effect of the learning analytics approach on increasing students' multiple representation skills.

METHODS

Research Design

This research is quantitative with experimental research design. The research instrument consists of lesson plan and multiple representation test. Six validators validated the lesson plan before being used in the experiment. Furthermore, students' skills were tested in six different schools. The research flowchart is presented in Figure 1.

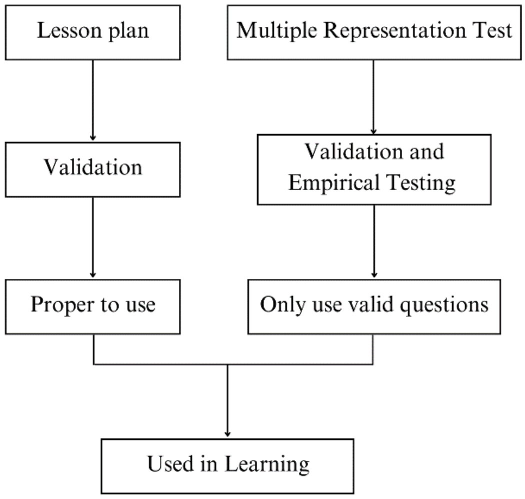

Figure 1. Research Flowchart

This research involved two classes: the control class (scientific learning approach) and the experimental class (learning analytics approach). The control and experimental classes were determined by cluster random sampling through drawing lots (Little et al., 2020). The research design is presented in Table 2.

Table 2. Pretest-Posttest Control Group Design

Class	Pretest	Treatment	Posttest
Control	O_1	X_1	O_2
Experimental	O_1	X_2	O_2

O_1 is a pretest, O_2 is a posttest, X_1 is the scientific learning approach treatment, and X_2 is the learning analytics approach treatment.

Participants

There were six validators to assess the lesson plans: two material expert validators and four practitioner validators. Before experimenting, an empirical test of the instrument was carried out in four schools, as displayed in Table 3.

Table 3. The Empirical Test Respondents

Respondent's school	Number of Classes	Number of Students	Total
SHS A	4	36	144
SHS B	2	36	72
SHS C	2	36	72
SHS D	6	36	216
		Total	504

To see the effect of the approach on multiple representational skills, the research was carried out in two classes with almost the same pretest scores. The samples were the twelfth-grade science class students in one of the senior high schools in the Special Region of Yogyakarta. The number of respondents is displayed in Table 4.

Table 4. Number of Respondents

Class	Respondent
Control	33
Experimental	34

Data Collection

This research gathered quantitative data based on the validation and the students' pretest and posttest results. The lesson plan was validated by six validators using Aikens V formula as follows (Aiken, 1985):

$$V = \frac{\sum (r - l_0)}{n(c-1)} \tag{1}$$

Notes:

V : Aiken's V validation index
r : Scores by the validators
l_0 : Lowest validation score
n : Number of validators
c : Highest validation score

Index Aiken's V is valid based on the criteria in Table 5 (Sholihah et al., 2020).

Table 5. Aiken's V Validity Criteria

Aiken V Index	Criteria
$0.0 < V \leq 0.2$	Poor
$0.2 < V \leq 0.4$	Low
$0.4 < V \leq 0.6$	Moderate
$0.6 < V \leq 0.8$	High
$0.8 < V \leq 1.0$	Excellent

multiple representation skills were analyzed using the normalized gain test to see the increase after learning. The results of the normalized gain test can be interpreted according to Table 6.

Table 6. The Criteria of Normalized Gain

Average Score Interval	Criteria
$\langle g \rangle > 0.7$	High
$0.3 \leq \langle g \rangle \leq 0.7$	Medium
$\langle g \rangle < 0.3$	Low

The multiple representation pretest and posttest results were analyzed using statistical descriptive analysis and paired sample t-test. However, before the paired sample t-test, a prerequisite test for normality was conducted.

RESULTS AND DISCUSSION

Lesson Plan Validation

The lesson plan was structured so that the learning ran as planned. The lesson plans were prepared in stages on a learning analytics approach and cooperative learning models. Before being used for learning, the lesson plans were validated by two expert lecturers and four practitioners (physics teachers). The validation results are shown in Table 7.

Table 7. The Results of the Lesson Plans Validation

Indicator	Indeks Aiken's V	Criteria
Identity Completeness	1.00	Excellent
Time efficiency	0.94	Excellent
Conformity of indicators with core competencies and basic competencies	1.00	Excellent
Indicator compatibility with multiple representations	1.00	Excellent
Conformity of the formulation of objectives	1.00	Excellent
Material	1.00	Excellent
Selection of learning models	0,89	Excellent
Appropriateness of learning activities	1.00	Excellent
language clarity	0.94	Excellent
Language spoken: "Indonesian."	1.00	Excellent

The validation was analyzed with Aiken's V equation, resulting in an Aiken's V index score. The criteria for the validation results are in Table 3. Based on the validation results in Table 5, each lesson plan indicator obtained excellent results. Therefore, the lesson plans could be used in learning.

Data analysis

The study of direct electric current was carried out with two different approaches. The control class used the scientific learning approach, and the experimental class used the learning analytics approach. The learning model in both classes was cooperative. This model was chosen because it was the easiest to apply and suitable for learning the physics of direct electric current material. The control class used the scientific learning approach because this approach is often used in the learning process, while the analytic learning approach has not been used in physics learning in high schools.

The instruments were pretest and posttest. The instruments had been validated previously and an empirical test was carried out to see the feasibility of the questions. Table 8 presents the indicators for each item and sub-matter of direct electric current.

Table 8. Indicators for Each Item

Sub Material	Multiple Representation Indicator	Item Number
Measuring electric current and voltage	Students can use image and mathematical representation skills.	1,2
Ohm's law	Students can use image and mathematical representation skills.	3,4
Electrical resistance	Students can use image and mathematical representation skills.	5,6
Kirchhoff's law	Students can use image and mathematical representation skills.	7,8
Energy and Power	Students can use image and mathematical representation skills.	9,10

The representations developed were images and mathematics because not all material can be presented in graphic form. The pretest was carried out before the treatment, and the posttest was carried out after the treatment. The prerequisite tests were the normality and homogeneity tests. The normality test results are presented in Table 9.

Table 9. The Normality Test Results

	Group	Shapiro-Wilk		
		Statistic	df	Sig.
Pretest	Control Class	.952	30	.191
	Experimental Class	.960	32	.275
Posttest	Control Class	.953	30	.205
	Experimental Class	.939	32	.070

Based on Table 9, all the significance values obtained results are more than 0.05. It means that the data obtained are normally distributed. The second assumption test was the homogeneity test, presented in Table 10.

Table 10. The Homogeneity Test Results

	Levene Statistic	df1	df2	Sig.
Pretest	.146	1	60	.704
Posttest	1.227	1	60	.272

Based on Table 10, the significance value is more than 0.05. Therefore, the research data is homogeneous. All assumption tests were met and continued with paired sample t-test analysis.

Table 11. Paired Samples t-Test Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest-posttest	-25.2	12.30	1.56	-28.33	-22.078	-16.13	61	.000

Based on Table 11, the sig. (2-tailed) value is 0.000, lower than 0.05. Therefore, there is an influence of the learning approach on increasing the multiple representation skills. To see the higher effect of the two approaches, a normalized gain test was performed.

Table 12. Normalized Gain Test Results

Test	Preset	Posttest	N-gain	Criteria
Control Class	45.08	65.92	0.38	Moderate
Experimental Class	45.78	75.08	0.54	Moderate

Table 12 shows that the control and experimental classes are in the moderate criteria because the questions' difficulty level is higher and requires deeper analysis. In addition, the medium range of the N-gain criterion is longer than low and high. However, the results in the experimental class were higher than the control class.

The difference values between the control class (0.38) and the experimental class (0.54) indicate that the learning analytics approach is better for direct-current circuit material. The N-gain value for each indicator is presented in Table 13.

Table 13. N-gain for Each Sub-material

Sub material	N-gain			
	Control	Criteria	Experimental	Criteria
Measuring electric current and voltage	0.53	Medium	0.77	High
Ohm's law	-0.01	Low	0.34	Moderate
Electrical resistance	0.65	Medium	0.90	High
Kirchhoff's law	0.17	Low	0.12	Low
Energy and Power	0.60	Medium	0.56	Moderate

Based on Table 13, the control class’s level of multiple-representational skills is moderate and low. At the same time, the experimental class’s level of multiple representation skills is high for measuring current and electric resistance materials, moderate for Ohm's law and Kirchhoff's law materials, and low for the energy and power materials. In general, the experimental class had better results than the control class. However, in Kirchhoff's law material and energy and power, the control class obtained better results because the emphasis was on mathematical calculations.

The difference in the N-gain value was not too significant in addition to increasing the ability of multiple representations for each class. The student's ability level for each sub-material can be calculated.

The multiple representational skill in each sub-material of the direct current circuit is presented in Table 14.

Table 14. Multiple Representation Achievement Results

Sub-material	Student Achievement
Measuring electric current and voltage	87.5%
Ohm's law	47.2%
Electrical resistance	87.1%
Kirchhoff's law	55.6%
Energy and Power	75.8%

Based on Table 14, the lowest achievement is in the Ohm's law sub-material, namely 47.2%. In this sub-material, the students were expected to represent graphically and mathematically. They could use the skills to multi-image and mathematical representation quite well. As for graphical and mathematical representations, students lack mastery.

Based on these data and discussions, the analytics approach improved students' skills to identify the material as a whole so that they can improve learning outcomes in theory and practice (Viberg et al., 2018). The Learning Analytics (LA) approach allows students to explore more about a material. For example, during learning at school, students can use data obtained from practical results as a reference for thinking more critically about why something happens and the skills to represent problems from various views. This finding aligns with LA's main concern, which is using data to enhance learning (Clow, 2013). The LA approach also allows learning with quite a lot of material but can be carried out effectively because the students can find literature sources from anywhere. Therefore, the LA approach can optimize learning (Dawson et al., 2019). The LA approach can be used for analytical learning, such as data processing, quantitative practicum, etc. The LA approach is not suitable when used for rote and theoretical material without any data in it. Therefore, teachers must pay attention to the appropriate approach to maximize student learning outcomes.

In the future, developing a learning model that can improve students' multiple representational skills focused on graphics and mathematics is necessary. Thus, the students can improve their multiple representation skills. On the other hand, the students can also improve their analytical skills because they determine their practicum titles and objectives according to the material. The limitations of this research were that the researchers were not the teachers at the school. As a consequence, they did not know the characteristics of each student.

CONCLUSION AND SUGGESTION

The learning analytics approach for learning direct-current circuits begins with a compilation of learning stages, followed by developing a lesson plan. The lesson plan validation produces very high results for each indicator, indicating that the lesson plan is suitable for learning. With the acquisition of the moderate N-gain score, the learning analytics approach positively affects students' multiple representation skills. However, students cannot develop all representational skills. The combination of image and mathematical representations yielded good results, whereas the combination of graphic and mathematical representations did not. As a result, for future research, a product or learning model can be created to improve the multiple representation skills by combining graphs and mathematics.

The research is limited to physics subjects and direct-current circuit material. Thus, it does not cover using learning analytics approaches for all physics material. It is possible to re-evaluate the learning analytics approach using different materials. However, it is recommended to use a learning analytics approach for material that requires deeper analysis.

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AUTHOR CONTRIBUTIONS

AA compiled research instruments, conducted research, and processed data. HR was a supervisor who always provided input and suggestions regarding this research. HR controlled and checked research progress.

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