Development of DICTY-AR Integrated Local Wisdom to Improve Multiple Representation and Problem-Solving Skills

Arshi Alfianti*, Heru Kuswanto, Anggi Datiatur Rahmat, and Reno Nurdiyanto

***Abstract*—This study aims to develop augmented reality (AR) as a learning media that can be accessed on smartphones to improve students' multiple representation and problem-solving skills, named direct current electricity-augmented reality (DICTY-AR). The media integrated with Javanese local wisdom '*Wayang*' performance to make learning more interesting and closer to the student environment. The development adopted the 4D model. Two content experts, two media experts, and four practitioners validated the media. The validation result of the developed media shows a V index between 0.80–1.00 for all aspects with very high categories. The readability test was administered to 20 students and gained very good results. Therefore, it can be concluded that DICTY-AR is suitable for learning direct current electricity as a physics concept. An expanded test was conducted to see the effectiveness of the media was developed. DICTY-AR effectively contributed 89.7% in learning physics to improve students' multiple representation and problem-solving skills. Learning using DICTY-AR is more effective and positively impacts students in learning physics.**

***Index Terms*—Augmented reality, local wisdom, multiple representations, physics, problem-solving**

I. Introduction

Education plays an essential role in improving human thinking abilities and being influential in creating an intellectual generation [1], one of which is in senior high school. Physics is one of the subjects often considered difficult by students because it has complex concepts [2]. Direct electric current is one of the many physics materials that students consider abstract [3], especially in Kirchhoff's Law material, with a percentage of difficulty reaching around 71.42% [4]. Furthermore, problem-solving related to direct current electricity requires skills and knowledge of many micro-objects. Most physics learning gives materials without involving the role of students [5]. This causes students to tend to be passive and makes them not develop their thinking skills [6].

On the other hand, students must think critically and creatively and solve problems [7, 8]. There are several possible reasons for students' failure to solve problems, misconceptions, mistakes in understanding relevant knowledge, difficulty making conclusions, and reliance only on intuition. Teachers and students require alternative teaching materials in physics [9]. Therefore, it is necessary to have teaching media interactive for direct current electric who have abstract concepts.

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Information and communication technology (ICT) is one of the main skills students need in this era [10]. Current teaching emphasizes digital literacy, authentic problem-solving, and the use of technology in the learning process [11]. The development of increasing technology positively impacts learning activities and gives new ideas and innovative ideas like integrating interactive media into the learning process. The rapid technological advances should be able to be utilized in learning physics activities. One of the developments of technology-integrated teaching media is augmented reality (AR). The application of media with AR technology in the learning process can create teaching more interactive [12, 13]. In physics education, AR presents phenomena that are difficult to observe in reality [14]. AR is technology based on real events and imaged by virtual, providing a more intuitive and natural way to teach and interact with information and creating a high curiosity to explore for students. AR is expected to increase students' willingness to learn [15, 16]. AR technology has the advantage of giving real experience, which facilitates abstract concepts, is difficult to observe in real life, and is possibly dangerous in the classroom environment [17]. Therefore, learning physics using AR technology can visualize abstract direct current material, creating more interactive and meaningful learning for students.

Indonesia is one of the countries have various cultures with local wisdom in each region, which must be maintained [18]. Local wisdom contains values that are instilled in a society [19]. Implementing the values of a nation's local wisdom in teaching becomes crucial. Building a personality to preserving values of the nation's culture [20]. Teachers must integrate local wisdom into physics teaching for meaningful learning [21]. Integrating local wisdom into learning physics can increase students' multiple representation and higher-order thinking skills (HOTS) [18]. *Wayang* is local wisdom in the Javanese culture and is relevant to the direct electric current material. This culture allows students to think about the series of electric tools used in the event procession. Integrating *Wayang* performance with AR technology into learning physics is expected that students can improve their multiple representation skills.

The representation skill is very important in physics learning. Visual representations can communicate ideas in the science classroom [22]. Scientific objects can be visualized in a static or dynamic form. The types of representation are generally divided into three, such as verbal, graphic, and mathematical [23]. The combination of several representations is called multiple representations. Students require training to develop multiple representation abilities. Multiple representations can encourage them to build in-depth understanding [24]. Another reason for using representations in physics learning is the structure of physics

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itself [25], especially in direct electric current topics. Students must understand the graph in the experiment and be supported by mathematical calculations.

The multiple representation skill of students can also be reviewed through physics problem-solving [26]. Students need problem-solving skills during learning physics [27]. The high mistake in understanding physics concepts is due to the inability of students to understand the content and basic principles [28]. In addition, problem-solving can be used as an organizing process of cognitive and affective behaviour [29]. Developing creative teaching to help students improve their abilities [30]. Teaching with multiple representations can improve students' problem-solving skills [31]. The research aims to develop AR technology integrated with local wisdom for direct electric current material to improve students' multiple representation and problem-solving skills in learning physics. The developed media is named direct current electricity-augmented reality (DICTY-AR).

II. Methodology

A. Research Design

The type of study is Research and Development (R&D) with a 4D development model that was adopted which consists of four steps: define, design, develop, and disseminate [32]. The stages in this research are presented in Fig. 1. In the dissemination stage, the media tested the effectiveness of the DICTY-AR media that was ready to be used.

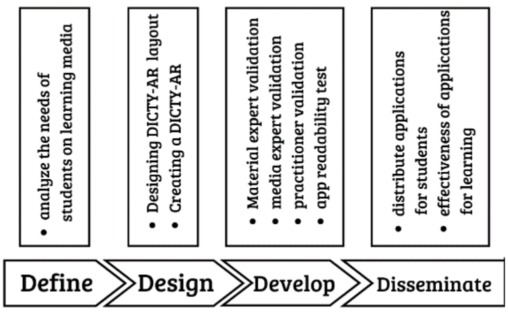


Fig. 1. 4D model stages.

B. Participants

In the developed media, a feasibility test was carried out involving two content experts, two media experts and four practitioners. The experts were selected according to their areas of expertise. The media readability testing was carried out by involving 20 students in senior high school. Then, the effectiveness test was carried out in three classes with different numbers of students, as shown in Table I.

TABLE I: Total of Participants

Test	Participants	Total
Feasibility	Material content expert	2
	Media expert	2
	Practitioners	4
Readability	Students	20
Effectiveness	Class A (DICTY-AR)	32
	Class B (PhET simulation)	35
	Class C (Textbooks)	28

C. Data Collection Instrument

The data collection instruments in this study are media validation sheets (content and media) and the student response questionnaire. The media validation sheet assessed the developed DICTY-AR as a learning media with pre-determined indicators [33]. Product assessment was divided into three parts, such as the assessment of content experts, media experts, and practitioners. The difference between the three parts is in the aspect being assessed. The validation sheet used a 4-point *Likert* scale, explaining each score shown in Table II.

TABLE II: Explanation of Each Score of the *Likert* Scale

Point	Explanation
4	fulfill the criteria of three indicators
3	fulfill the criteria of two indicators
2	fulfill the criteria of one indicators
1	does not fulfill all indicators

The student response questionnaire consisted of 12 questions and one comment column for the readability test. The questionnaire used the *Guttman* scale. The data obtained were nominal data with a score of 0 for a negative answer 1 for a positive answer [34]. The data obtained from the validation sheet and questionnaire were quantitative data and qualitative. The quantitative data were in the form of scores assigned to the developed media, while the qualitative data were comments and suggestions for improving the developed media.

To determine the effectiveness of the developed media on multiple representations and problem solving skills, tests were carried out on three different classes (See Table I). This effective test uses ten essays and ten reasonable multiple-choice to evaluate multiple representation and problem-solving skills for pre-and post-test.

D. Data Analysis

This study used quantitative data from the validation results of the developed media and student readability. The media content validation testing used Aiken's *V* based on the results of *n*-validators. Aiken's *V* equation is as follows in equation (1) [35], and criteria valid is shown in Table III [36].

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

Notes:
V = Aiken's V validation index
r = scores are given by validators
l_0 = lowest validation assessment score (in this case = 1)
n = number of validators
c = highest validation assessment score (in this case = 4)

TABLE III: Aiken's V Validity Criteria

Aiken V Index	Criteria
$0.0 < V \leq 0.2$	Very Low
$0.2 < V \leq 0.4$	Low
$0.4 < V \leq 0.6$	Medium
$0.6 < V \leq 0.8$	High
$0.8 < V \leq 1.0$	Very High

The readability testing was examined by involving 20 students using a questionnaire with the *Guttman* scale. The assessment result was calculated for each indicator's average value. The calculation of the average score used the following equation.

$$X = \frac{\sum x}{n} \qquad (2)$$

With $\sum x$ is the sum of all respondents' scores for one indicator, and n is the number of respondents. The analysis of this readability test used the ideal standard deviation (ISD) with the criteria presented in Table IV, with the X value being each indicator's average score.

TABLE IV: CATEGORY OF STUDENT RESPONSE QUESTIONNAIRE

Score	Category
$X \le Xi - 1.8$ ISD	Very poor
$Xi - 1.8$ ISD $< X \le Xi - 0.6$ ISD	Poor
$Xi - 0.6$ ISD $< X \le Xi + 0.6$ ISD	Fair
$X_i + 0.6$ ISD $< X \le X_i + 1.8$ ISD	Good
$X > X_i + 1.8$ ISD	Very good

Data analysis on effective tests to evaluate multiple representation and problem solving skills using rubrics for essays and reasoned multiple choice with a score of 1–4. The reasoned multiple choice scoring rubric is shown in Table V. Furthermore, to determine the effect on each class, a MANOVA analysis was carried out using SPSS program.

TABLE V: SCORING REASONABLE MULTIPLE CHOICE

Score	Answer	Reason
4	Correct	Correct
3	Correct	Incorrect
2	Incorrect	Correct
1	Incorrect	Incorrect

III. FINDINGS AND DISCUSSION

A. *Define Stage*

The first stage in the developed media is defined, where the researchers determine the objectives of developing DICTY-AR. The aim of developing the media paid attention to the needs of students, ease of learning, and integrating technology into the learning process. Based on student feedback, the media used was student textbooks, occasionally searching on internet for find learning materials. Students had difficulty acknowledging physics concepts [37].

The development of this media was designed to facilitate students in learning activities at school or at home, visualization of the passage of electrons in the circuit using *Wayang* performance, and practice questions that could be done repeatedly. This media is expected to satisfy students' needs, so the DICTY-AR was designed to facilitate multiple representation and problem-solving skills in learning physics.

B. *Design Stage*

The next stage is design who researchers are designed and compiled the DICTY-AR. This media is designed to facilitate students in understanding the concept of direct current electricity and to facilitate multi-representation and problem-solving skills in physics learning. The developed media includes competencies that must be achieved, learning activities, AR visualization, simple virtual laboratories, exercise questions, and developer profiles. The language used in the developed application is Indonesian. The first step in the design stage was to create the application layout. The display of several layouts is shown in Fig. 2.

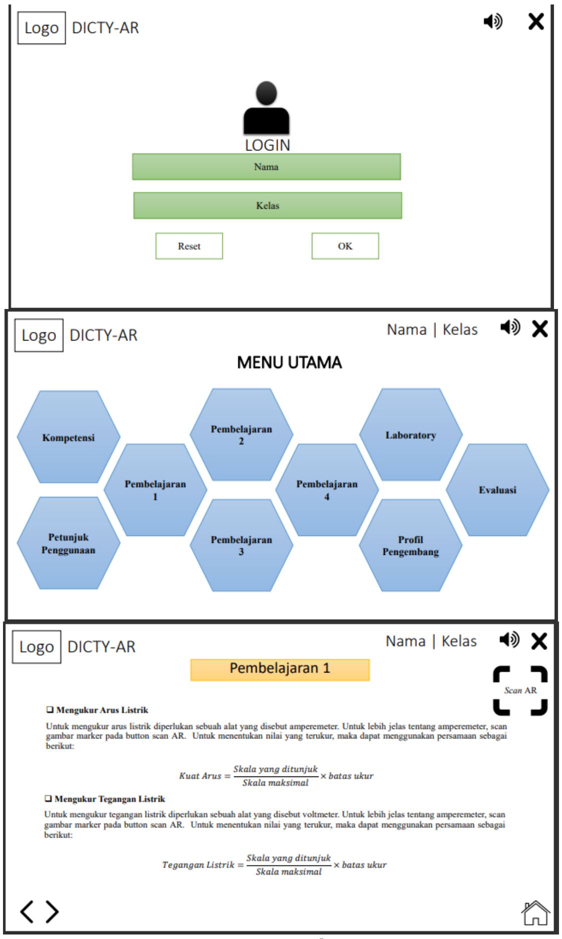


Fig. 2. Layout design.

Based on the layout design, the application was built using the Vuforia SDK and Unity 3D. The application can be capable in Android users with a minimum specification of 5.0 lollipops and API level 21. This application is equipped with verbal, mathematical, graphic representations, AR, and video visualization to clarify a phenomenon as shown in Fig. 3. This representation is necessary in learning physics [38], so students understand more fully and thoroughly.

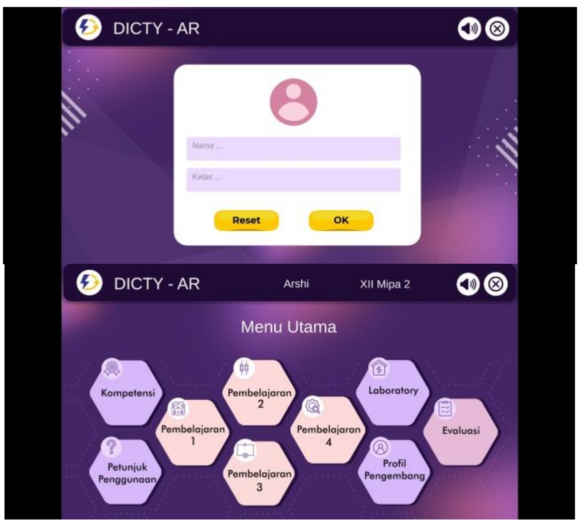
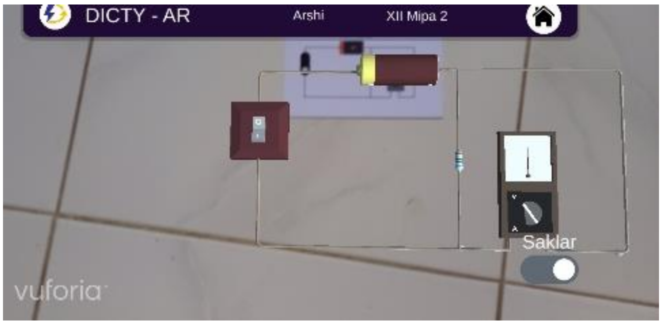
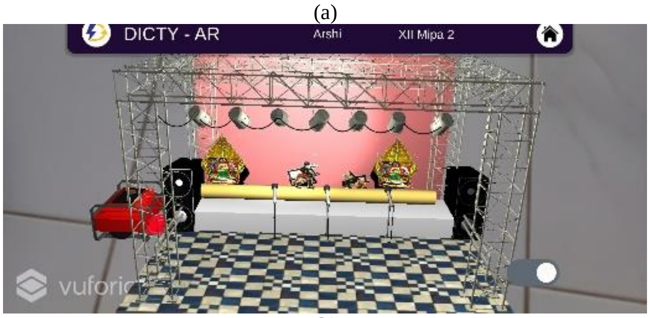


Fig. 3. Display on DICTY-AR application.

This media is also equipped with music, so students are more comfortable learning with this application. In this media also have content with AR display about the passage of electrons in parallel and series circuits and the correct installation of measuring instruments; visualization of *Wayang* performance as shown in Fig. 4



(a)



(b)

Fig. 4. Visualization AR in application.

Fig. 4(a) shows the illustrate electrons in the circuit. AR display (parallel and series circuits), electrons can shift in their direction and branch. This AR visualization is expected to increase students' understanding of series and parallel circuits. So that the description of the flow of electrons and electric currents can be understood. Besides, Fig. 4(b) is visualization *Wayang* performance using AR with 3D simulation and can be rotated, allowing students to see the real thing. Some visualized electrical components are equipped with certain cables, circuits, generators, sound systems, microphones, *Wayang*, and lighting, so students can analyze them. In addition, when the switch is turned on, the lights and music are on, so students feel as if they are in a *Wayang* performance.

Integrating *Wayang* performance is expected to improve students' analytical skills. Analyze the electrical circuit, the number of resistances, generator efficiency, and the power required in staging. So that students are familiar with the problem even though it is in the form of pictures. Students who use this application are expected to be able to understand the problem more concretely so that they can solve problems with multiple representations.

C. Develop Stage

The developed media is named DICTY-AR, and the material discussed is direct electric current. After the media was designed, the next stage is developed. The developed media must be an assessment to expert validators, including content and media. The result of the validation of expert content and media is presented in Table VI.

TABLE VI: RESULT OF DICTY-AR VALIDATION BY MEDIA AND CONTENT EXPERTS

Indicator	Media validator	Content validator	Index	Category
Media Design	4	4	1.00	Very high
Visual Quality	4	4	1.00	Very high
Content	4	4	1.00	Very high
Presentation	4	4	1.00	Very high
Content Coverage	4	4	1.00	Very high

Table VI shows that all barometers of the developed DICTY-AR have a very high category. Besides that, DICTY-AR was also assessed by four practitioners, and the result is presented in Table VII.

TABLE VII: RESULT OF DICTY-AR VALIDATION BY PRACTICIONERS

Indicator	P1	P2	P3	P4	Index	Category
Ease-of-use perception	4	4	4	3	0.92	Very high
Perception of uses	4	4	3	4	0.92	Very high
Attitude	4	4	4	4	1.00	Very high
Real system uses	3	3	4	4	0.83	Very high

P: Practicioners

After validating the DICTY-AR, the next test is the readability test with limited participant, which is only 20 students grade XII junior high school. Each student installed the application and accepted a marker image to be scanned on the application. After the application was used in physics learning, the students responded to the DICTY-AR; the result is shown in Table VIII.

TABLE VIII: RESULT OF READABILITY TEST

Indicator	Mean score	Category
Ease-of-use perception	1.00	Very good
Utility sensed	1.00	Very good
Attitude	1.00	Very good
Real System uses	1.00	Very good

The result of readability test is categorized as very good with a value of $X_i = 0.5$ and ISD = 0.167, and thus the value of X_i + 1.8 ISD = 0.8. The result obtained exceeds the value or 1.00 > 0.8. After the validation and readability test result was declared good and feasible, the next step was to apply and disseminate the DICTY-AR application in classroom teaching-learning activities.

D. Disseminate Stage

This dissemination stage includes registering product copyrights, distributing applications to teachers and students in the Yogyakarta area, and using DICTY-AR in learning physics. There are three broad trial classes (See Table I): Class A using DICTY-AR, Class B using PhEt simulation and Class C using textbooks. Each class was given the same pre-test and post-test questions. After the MANOVA analysis with SPSS, the following result is obtained.

TABLE IX: NORMALITY TEST

Variable	Class	Sig.
Pre-test Multiple Representation	A	0.066
	B	0.055
	C	0.228
Post-test Multiple Representation	A	0.146
	B	0.073
	C	0.271
Pre-test Problem Solving	A	0.058
	B	0.174
	C	0.123
Post-test Problem Solving	A	0.187
	B	0.054
	C	0.095

The normality test was carried out to determine whether the data used in the study were normally distributed before further tests were carried out. The normality test used is the Shapiro Wilk. Table IX found that the significance value is obtained with a value of 0.055–0.271 so that it can interpreted that all the data used is more than the significance level of 0.05. Therefore, each data to measure the increase in multiple representation and problem-solving skills for all classes is normally distributed.

TABLE X: BOX'S TEST OF EQUALITY OF COVARIANCE MATRICES

Box's M	Sig.
F	1.032
df1	20
df2	28345.651
Sig.	0.419

Table X shows the homogeneity of research data. The significance value in Box's is 0.419. This value is certainly higher than the 0.05 significance limit. In addition, homogeneity is also seen from Levene's Test for each data. The data used in this study are pre- and post-test multiple representation and pre-post-test problem-solving.

TABLE XI: LEVENE'S TEST

Variable	Levene Statistic	df_1	df_2	Sig
Pre-test Multiple Representation	1.288	2	92	0.281
Post-test Multiple Representation	1.281	2	92	0.283
Pre-test Problem Solving	0.028	2	92	0.972
Post-test Problem Solving	0.624	2	92	0.538

The result on Table XI shows that the significance of the four data groups are more than 0.05 so that each data group has the same variance. If the significance value is >0.05 then the data is said to be homogeneous [39, 40]. This means that all classes' research data for multiple representation and problem solvings variables are homogeneous.

TABLE XII: TESTS OF WITHIN-SUBJECT EFFECT

Source	Measure	Sig.
time*group	MEASURE-1	0.000
	MEASURE-2	0.000

The output for the tests of within-subject effect in Table XII explains whether or not there is an interaction between time (pre-test and post-test) and group (contrast-experimental). Based on Table VIII, the time*group column has a significance value of 0.00, which means that the significance value is more than 0.05 and so it can be said that there is an interaction between time and group. The interaction shows that the changes in the pre-test and post-test scores in the three classes are significantly different.

TABLE XIII: MULTIVARIATE TEST

Class	Sig.	Partial Eta Square
A	0.000	.897
B	0.000	.868
C	0.000	.633

Table XIII shows the multivariate test results where the partial eta square (Wilks' lambda) can be reviewed. These results determine the value of the effective contribution of the media to increase multiple representation and problem-solving skills.

In Class C, the partial eta square is 0.633,it can be interpreted that the textbooks used in the learning process can increase multiple representation and problem-solving skills by 63.3%. In Class B, the partial eta square is 0.868, meaning that the PhET simulation used in learning process can increase multiple representation and problem-solving skills by 86.8%. While in the class A, the partial eta square is 0.897, meaning that the DICTY-AR used in the teaching-learning process can increase multiple representation and problem-solving skills by 89.7%. The effectiveness of this media, in terms of the skills of multiple representations and problem solving of students. The indicators and student achievement of each class are shown in Table XIV.

TABLE XIV: STUDENT ACHIEVEMENT

Variable	Question Indicator	Class	Student Achievement
Multiple Representation	Students are expected to be able to apply mathematical and graphs representations	A B C	87.50% 75.87% 76.50%
	Students are expected to be able to apply mathematical and pictorial representations	A B C	78.11% 63,38% 57.11%
Problem solving	Students are expected to be able to compose a series with pictures and calculate physical quantities	A B C	57.29% 48.26% 41.67%
	Students are expected to be able to solve a problem in voltage and electric current	A B C	54.17% 53.13% 40.28%
	Students are expected to be able to provide solutions to the problem of a series of obstacles	A B C	52.78% 50.69% 31.60%
	Students are expected to be able to solve cases related to Ohm's law and Kirchhoff's Law	A B C	74.31% 62.85% 42.36%
	Students are expected to be able to analyze and solve cases regarding problems of energy, power, and their application in everyday life	A B C	79.51% 54.17% 34.72%

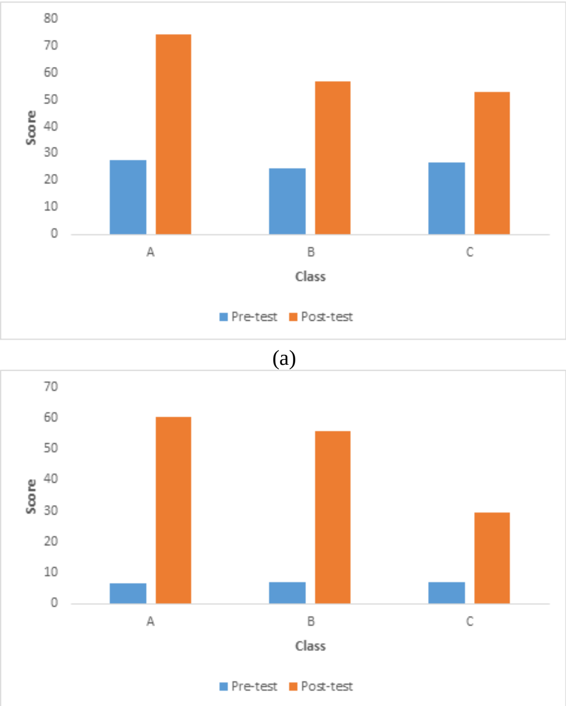
Table XIV shows that class A obtained the highest student achievement compared to classes B and C. Also, students' achievement in class B was higher in class C. The result can be interpreted that student achievement A > B > C. In addition to the student achievement of each indicator, Table XV explains the completeness of each question instrument.

TABLE XV: STUDENT COMPLETENESS

Class	Multiple representation	Problem-solving
A	59.38%	40.63%
B	28.57%	11.43%
C	10.71%	3.57%

Table XV shows the completeness of students with a minimum criterion of 75.00, these results are obtained. Class A obtained the highest completeness, namely 59.38% for multiple representation skills and 40.63% for problem-solving skills. The result can be interpreted that about half of the students in class A still have not achieved the minimum criterion.

Based on the two skills tested, the completeness of students' problem-solving skills is still very low compared to the multiple representation skills. This is because students are not used to solving complex problems, so it is necessary to develop more learning media or methods to improve problem solving skills.



(b)

Fig. 5. Result of pre-and post-test in each class (a) multiple representation skills and (b) problem-solving skills.

Based on the graph in Fig. 5a, the class A obtained much better results than class B and C. It means that the multiple representation skills of students in class A are higher than those in other classes. While in Fig. 5b, the class A and B have almost the same increase, although the increase is higher in the class A. This means that the students in the class A who used DICTY-AR and class B use the PhET Simulation have higher problem solving skills than those in class B used textbooks only.

Class A has the highest effectiveness compared to the two classes and significantly increases. This is because the students are more motivated in learning. The students' high learning motivation can affect the quality of teaching [41] so that teaching objectives can be achieved [42]. Students with high learning motivation can improve their learning achievement [43].

The multiple representation skills of students in the Class A is higher than class B and C. This is because students can imagine abstract electric currents with AR visualization. In addition, the students' problem-solving skills in the class A also increases higher than those in the class B and C. Integrating local wisdom can build the character of students [44, 45], improve learning achievement [46], and make learning more meaningful [18, 47]. So that students can analyze the problems that occur in a case in physics problems.

IV. CONCLUSION

This study aims to develop Android-based learning media to improve students' multiple representation and problem-solving skills. The developed media is called DICTY-AR (Direct Current Electricity-Augmented Reality). This application was assessed by validators consisting of content and media experts and practitioners. The result shows that the developed media is in the 'very high' category. The readability testing involving students scored in the 'very-good' category. Therefore, the DICTY-AR application is suitable for use in learning physics. Also, this study identify the effectiveness of the developed media. DICTY-AR is effectively contributes 89.7% to improving students' multiple representation and problem-solving abilities. This result showed that learning using DICTY-AR is higher than the two classes other with an effective contribution of 63.3% and 86.8%, respectively. Therefore, it can be conclude that the DICTY-AR can significantly improve students' multiple representation and problem-solving skills.

The implication of this research is necessary to develop an application based on Android and IOS to improve the abilities of other students. This is because students must improve other abilities besides multiple representation and problem solving.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

AA discovered problems regarding physics learning in schools, compiled research instruments, retrieved research data, analyzed data, and compiled reports. HK reviewed and monitored the research progress and provided input on the research. ADR reviewed and edited the language and reviewed the compiled articles, and RN developed the DICTY-AR. All authors have approved the final version of the article.

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