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Mobile Learning based Worked Example in Electric Circuit (WEIEC) Application to Improve the High School Students' Electric Circuits Interpretation Ability

Mitra Yadiannur[a] and Supahar[a]

[a]Yogyakarta State University, Yogyakarta, INDONESİA

ABSTRACT

This research aims to determine the feasibility and effectivity of mobile learning based Worked Example in Electric Circuits (WEIEC) application in improving the high school students' electric circuits interpretation ability on Direct Current Circuits materials. The research method used was a combination of Four-D Models and ADDIE model. The research design used was a pretest-posttest control group design using quantitative approach. The data collection instruments in this research were non-test and test instruments. The non-test instruments consist of product feasibility instrument, materials feasibility instrument, and preliminary field testing instrument. The test instruments were the pretest and post test data. The data analysis technique used was Aiken's V to assess the product quality of the WEIEC application and General Linear Model (GLM) Mixed Design test to determine the students' electric circuit interpretation ability improvement. The research subject were 9 experts judgement, 35 senior high school students of class XII for the preliminary field testing and 74 students for the main field testing. Research results showed that the developed WEIEC Application was considered feasible to use in terms of materials aspect assessment with the Aiken's V score of 0.80, media aspect with the Aiken's V score of 0.80 and preliminary field testing results on the students with the Aiken's V score of 0.81. The developed WEIEC application could improve the electric circuit interpretation ability based on the Mean Difference (MD) score of -28,811 with 85.8% effectivity based on Partial Eta Squared in Multivariate Test.

KEYWORDS
Mobile Learning,
Worked Example in Electric Circuits,
Direct Current Circuits,
Electric Circuits Interpretation Ability

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Introduction

One focus of learning physics is to improve the students' problem solving ability. The process in developing the students' abilities in physics needs to consider a strategy and learning methods which are effective and efficient. The aim is that students can absorb physics learning optimally and be able to

CORRESPONDENCE Mitra Yadiannur ✉ mitra.yadiannur2015@student.uny.ac.id

improve the students' problem solving ability. This is to fulfil the demands of the 21st century that emphasize on the aspects of learning and innovation abilities that include: creative thinking and innovation, critical thinking, problem solving, communication and collaboration, as well as the instructional media development (Kay, 2010).

One of the aspects of learning and innovation to fulfil the demands of the 21st century is problem solving. Educational research in cognitive domain showed that continuous problem solving exercises can evoke experience in taking a more complex solution (Chu & MacGregor, 2011), both for the work demands and in their daily lives. There are differences in responses between an expert and a novice in resolving a problem. It was stated by Chi, Feltovich, and Gleser (1998) which revealed that novice students have different methods in solving physics problems; an expert classifies a problem based on the principles in managing a process, a novice classifies based on the output structure of the problem.

Larkin and Rainard (1980) divided the problems in physics through the classification of a novice and an expert. Novice students begin a process by determining the objective of the problems through analysis of the differences between the objectives and the available information as well as the equations that can reduce differences, and then apply the equation. Expert students, on the other hand, use the development of knowledge or approach by starting it based on the provided information in the problem and conduct the process until they reach the final result. The researchers describe that in learning physics, some people are good in theory mastery, but do not know how to solve the problems of physics, both in terms of learning as well as in real life.

In solving a problem, a learning tool in the form of exercises that are able to teach problem solving ability to the students is needed. The exercises can be given in the form of worked example. Atkinson, Derry, Renkl & Wortham (2000) define Worked Example as a learning tool that provides solutions to problems from an expert to be used by the students in learning. The idea is how can one answers a problem that is not familiar to him by learning and following the steps to resolve the problem from a similar problem that has been solved. This opinion is supported by the research results conducted by some experts (Retnowati, Ayres, & Sweler 2010; VanLehn, 1996; Gog, Pass, & Merrienboer, 2006; Pass & Merrienboer, 1994) which showed that worked example assisted learners in solving a problem in a broad aspect, creating an effective and efficient teaching and providing better knowledge transfer.

Problem solving ability in physics is closely related to the use of mathematical physics equations and mathematics skills in finding the solutions. Mathematics and equations are regarded as physics language (Docktor, 2014). One important scope of physics materials is the Direct Current (DC) Circuits. Scaife & Heckler (2013) stated that there are two students' response patterns which are consistent and in contrast to the electric circuit, the first stating that greater equivalent resistors always has much power dissipation; the second, lower resistors always dissipates more power.

In line with those opinions, McDermott & Shaffer (1992) argues that one of the difficulties the students encounter in understanding the behavior of electric circuits is the students' inability to give a qualitative reason about the electric circuits behavior. To overcome this, a key element in understanding the electric circuits behavior is by creating and interpreting the electric circuit (Jill Marshall, 2008).

This study focuses on problem solving, with one important coverage which is the electric circuit interpretation ability, so this research will make a media to improve the students' electric circuit interpretation ability. The developed media is in the form of WEIEC which is a compilation of questions with answers that enable students to learn independently or in the classroom. The developed WEIEC is in the form of an application that can be used on mobile learning devices due to the huge percentage of mobile learning which spread out evenly across society.

Literature Review

There has been a lot of research and literature saying that worked example helps students improve their problem solving ability. This research focuses on the creation of mobile learning based worked example application to improve the electric circuit interpretation ability of high school physics which is an important coverage of problem solving. Until now, there has been no studies, especially in Indonesia which develops the worked example in the form of mobile learning applications, so this research aims to investigate the feasibility and effectivity of the mobile learning based worked example application in improving the students' electric circuit interpretation ability.

Mobile Learning

Education must play an active role in preparing educated human resources to face various challenges of the 21st century learning innovation. The use of mobile learning is one of the learning innovations to address these challenges. Mobile learning is a learning device that allows students to articulate the thinking process review, solve problems, and participate in the collaborative and thinking process (Kennedy & McNaught, 2001). Mobile learning has been conceptualized in a variety of perspectives, including theory activity (Uden, 2007; Maj. Winters, & Oliver, 2008), a learning community (Danaher, Moriarty, and Danaher, 2009), and theory learning (Sharples, Taylor, & Vavoula, 2007).

El-Hussein and Cronje (2010) said that mobile learning is a learning media that occurs in the environment and spaces that take into account the mobility of technology, mobility of students, and the mobility of teaching and learning that aim to make learning fun. Other opinions say, mobile learning is part of the educative process that contains learning supporting materials (Lynnette, 2013).

In the education world, mobile learning has become an educational resource. Increased educational resources from mobile technology makes learning access affordable, more personal interactive and effective for anyone who wants to learn (Mohammed & Joseph, 2014). In their research, Iqbal & Qureshi (2012) said that mobile learning provides benefits, ease of use, and ease the students in learning. Another research stated that mobile learning contributes to the improvement of educational outcomes in developing countries, especially in Asia (Volk, Rashid, & Elder, 2010).

Worked Example

Worked example (WE) is a learning device that is capable of improving the students' learning skills and is the solution to overcome the students' difficulties. This is proven by Renkl, Stark, Gruber, & Mandl (1998), and Atkinson, Derry, Renkl, & Wortham (2000) who explained that WE is a learning device that is able to teach problem solving ability which consists of modeling the process of solving problems in the structure domain like physics or mathematics by presenting examples of problems and show the steps of the solution as well as the final answer.

Sweller (1998) said that the purpose of using WE is to reduce the students' cognitive load when solving the problem. The use of WE reduces the random process that occurs in a person's thinking in calling the memory needed on the components that were found in problem solving and looking for correlations among them, so that the less random process that occurs, the more the memory process is allocated for learning (Sweller, 2006). Furthermore, Renkl (2014) states that the problem solving that is commonly used (conventional) namely asking the students to solve problems only after giving one example, has two weaknesses that are related. First, the conventional problem solving raises the cognitive load, and even pose excessive cognitive load for some students. Second, the resulting cognitive load has no relation to building problem solving ability, but just focusing on obtaining a solution of the exercise done.

There has been many research conducted by other experts (Pass & Merrienboer, 1994; Gog, Pass & Merrienboer, 2006; Gog, Liesbeth & Pass, 2011; Gerven, Pass, Merrienboer & Schmid, 2002; and Nievelsetein, Gog, Djick, & Boshuizen, 2013) related to WE. Those experts concluded that the use of WE in learning was more effective compared to the use of conventional problem solving method, in which students were given full control in solving new problems by using available learning resources. In other research, McLaren & Isontani (2011) explained that WE was really helpful for the students, especially for those who have low initial ability by reviewing examples of questions so that it reduced the cognitive load and optimized the initial learning. The cognitive scheme that is formed while learning the examples was then could be used to finish other question.

A few years back, learning from WE has received many considerations from researchers, particularly in fields such as mathematics, physics and computer programming (Atkinson, Derry, Renkl & Worthman, 2000). Many experts and practitioners have tried to develop and examine the structure and ways to conduct a good WE. Sweller (2006) gives some notes on the use of WE. Firstly, one WE for each learning will not give the WE effect. Second, after studying WE, students need a procedure, normally in the form of question, to give them feedback on what they have learned. Third, problem that is given after WE provides encouragement for students to actively process the WE. And fourth, the students not only need to learn the condition of the intended problem solving steps, but also need to learn the consequences of every step.

Renkl (2014) also provided special procedures to learn from WE in the following sequence: First, the principles (such as abstract rule, a mathematical theorem or the laws of physics) were introduced. Second, some WE are provided to portray how the principle was applied to problem solving. Third, when the students have gained an understanding of how to apply the principles, they then work on the problems to be solved.

Interpreting Electric Circuit

The electric circuit, especially in the direct current (DC) circuit is an important material in physics learning. Many studies have said that students have difficulty in understanding the behavior and misconceptions in an electric circuit. One of them is the opinion of Bilal & Erol (2009) which says that the students have some common misconceptions in the electrical material that is the electric field, the field lines, the field intensity, the electrostatic force, and electric circuits. It is strengthened by the results of research by McDermott & Shaffer (1992), and Shipstone & Cheng (2001) which suggest that many students have difficulty in understanding the electric circuit behavior. The students' difficulties are: (1) the inability to apply the formal concept in electric circuit in the form of difficulty towards the common nature of electricity, the lack of understanding of a real circuit, fail to understand and apply the concept of a complete electric circuit, difficulty with concepts related to electric current, the difficulty with the concepts related to the electric potential difference, and difficulties with concepts related to resistors; (2) inability to relate formal representation and numerical measurements in electric circuit; (3) the inability to provide a reason qualitatively about the habits of the electric circuit.

The research results of Li & Singh (2016) also revealed that there are misconceptions that students have toward electric circuit, especially in determining the brightness of the bulbs in the circuit, namely (1) the students assume that greater power is always brighter whether it is arranged in series or parallel; (2) fail to understand the correlation between the resistors on the bulbs and power dissipation; (3) consider that greater power for a constant voltage source will have a major resistors; (4) fail in understanding the basic of a parallel and series circuit; (5) in the series lights, students assume that in the first bulb that is close to the bigger voltage source than the second bulb, because the electric current flowing to the first bulb will cause a voltage drop so that the voltage in the next bulbs is reduced; (6) fail to understand that it is the power dissipation which determines the brightness of the bulb; and (7) the confusion in the concept of resistors, electric current, and voltage. It is also stated by Timmermann and Kautz (2014) who say that the students in Kirchoff law materials have difficulties in linking the concept between voltage and potential so that in the research concluded that the concept of voltage and potential is very different for the students in their learning process.

Engelhardt & Beichner (2004) suggested that female students tend to have more misconceptions than male students. Shipstone (2007) also said that the students have difficulty when the electric circuit diagram is made more complex, covering both fixed and variable resistor and connected in series or parallel. One way to fix the misconceptions is by creating and interpreting the electric circuit.

Jill Marshall (2008) describes a key element in understanding the electric circuit is to create and interpret the electrical circuit. Jill Marshall also said in his research, the two main things seen in interpreting the electric circuit are the ability to describe the electric circuit by describing the electric current flow in the circuit and the ability to orient the electric circuit based on the potential difference in each branch point. The research results indicate that students can be at loss when conventional electric circuit is only served as a measurement or a major benchmark without the explicit discussion on the issue of how to represent it. The research results conclude that in understanding the behavior or the nature of the electric circuit, students are required to be able to create or interpret an electric circuit in the sense of being capable of interpreting or simplifying the form of a circuit.

Chu & Rau (2010) describes four assessment indicators in determining the electrical circuit interpretation ability. Assessment indicators presented by Tsu Chu & Chin Riau are shown in Table 1.

Table 1. Assessment indicators of the electric circuit interpretation ability

Dimension	Indicator	Description
Interpretation of the Answers	Interpretation of the answers in the form of mathematical language	The ability to transform into mathematical language form The ability to present the issues in the form of mathematical equation The ability to understand the concept
	Telling results by using a mathematical equation	The ability to create relationships between variables The ability to read symbols in the problems
Interpretation of real life problems	Interpretation of the answers to the electric circuits problems	The ability to explain the results obtained in the problems The ability to think logically to the problems
	The best solution to the electric circuits problem	The ability to connect each variable and to make a simple circuit model form in resolving the problems

Meanwhile, Engelhardt & Beichner (2004) describes 11 indicators of the electric circuit interpretation. The indicators are shown in Table 2.

Table 2. Indicators of electric circuit interpretation ability assessment according to Engelhardt & Beichner

No	Indicators of Electric Circuit Interpretation
1	Identify and describe a short current
2	Understand the function of the two poles (+/-) of the circuit elements (elements have two points that are likely to make a connection)
3	Identify a complete circuit and understand the need of a complete circuit for continuous flowing current
4	Apply the concept of resistors, including series and parallel resistors
5	Interpret figures and diagrams of various circuits including series, parallel and series-parallel
6	Apply the concept of electric power towards various circuits
7	Apply the concept understanding of energy conservation including the Kirchoff law rules ($\Sigma V = 0$ around a closed loop) and a battery as the energy source
8	Understand and apply the current conservation from various circuits
9	Explain microscopic aspects of electric current flow in a circuit
10	Apply the knowledge that current is affected by a potential difference and resistors in the circuit
11	Apply the concept of potential differences towards various circuits including the knowledge that a potential difference in series circuits is summed while the potential in parallel circuit is the same

Synthesis of the electric circuit interpretation ability improvement assessment indicators that are the focus in this study are shown in Table 3.

Table 3. Synthetis of the electric circuit interpretation ability improvement assessment indicators

Indicators	Description
Telling results by using a mathematical equation	Able to apply the concept of resistors, including series and parallel resistors Able to apply the concept of electric power towards various circuits Able to apply the concept understanding of energy conservation including the Kirchoff law rules ($\Sigma V = 0$ around a closed loop) and a battery as the energy source Able to apply the knowledge that current is affected by a potential difference and resistors in the circuit
Interpretation of the answers to the electric circuits problems	Able to identify and describe a short current Able to understand the function of the two poles (+/-) of the circuit elements (elements have two points that are likely to make a connection) Able to identify a complete circuit and understand the need of a complete circuit for continuous flowing current Able to Interpret figures and diagrams of various circuits including series, parallel and series-parallel
The best solution to the electric circuits problem	Able to understand and apply the current conservation from various circuits Able to apply the concept of potential differences towards various circuits including the knowledge that a potential difference in series circuits is summed while the potential in parallel circuit is the same

Research Objective

To determine the feasibility and effectiveness of the worked example in electric circuits (WEIEC) application to improve the students' electric circuit interpretation ability.

Research Question

How is the feasibility of the worked example in electric circuits (WEIEC) application according to the experts and the students' judgement?

How is the effectiveness of the worked example in electric circuits (WEIEC) application?

Method

The method used is a combination of Research and Development (R & D) and 4-D models (Four-D Models) as well as the ADDIE Model. 4-D model consists of define, design, develop, and disseminate stages. While ADDIE is an acronym from analyze, design, development, implementation and evaluation. Simply put, the flow diagram of the combination of 4-D models and ADDIE and the chronological flow diagram of the development phase of WEIEC applications which can be seen in Figure 1 and Figure 2.

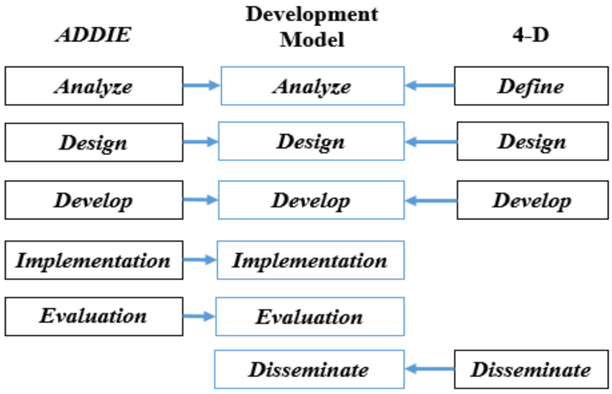

Figure 1. Diagram of Combination between ADDIE and 4-D Development Model

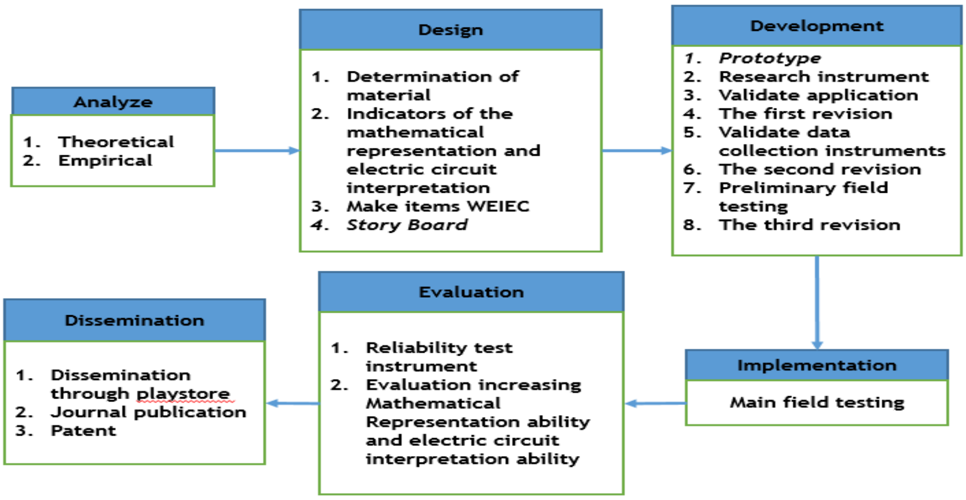

Figure 2. Diagram of Procedure Development Model

The research design employed was pretest-posttest control group design that can be seen in Table 4.

Table 4. Research Design

Group	Pretest	Treatment	Posttest
Experiment (E)	T_E	X_E	T_E
Control (C)	T_C	X_C	T_C

Participants

This research was conducted in Samarinda, East Kalimantan, Indonesia. The subjects involved are 9 Experts judgement, 35 students of class XII SMA 5 Samarinda for preliminary field testing, and 74 students of class XII SMA 5 Samarinda for main field testinging. The object of the study is the quality and feasibility of a learning media named WEIEC application, which is an aspect of material validation, media validation, worked example validation, empirical validation, and the improvement of the electric circuit interpretation ability.

Data Collection Instruments

Data collection instrument in this research were non-test instruments and test instruments. The non-test instruments consist of product feasibility instrument, materials feasibility instrument, and preliminary field testing instruments. The test instruments consist of pretest and posttest data to measure the students' electric circuit interpretation ability. Data analysis techniques used to assess the quality of the WEIEC application product is by using Aiken's V having a value between the range of 0 to 1 (Saifuddin Azwar, 2012: 134).

$$V = \sum s/[n(c-1)]$$

Meanwhile, to determine the improvement of the students' electric circuit interpretation ability, a statistical test consisting of the prerequisite test (normality test and homogeneity test), and GLM mixed design test analysis were employed.

Data Analysis

Data obtained were in the form of validity data on the quality of WEIEC application product assessed by 9 experts judgement and 35 students, reliability data of the electric circuit interpretation ability test instrument, and the pretest-posttest data on the high school students' ability in interpreting the electric circuit. Data validity of the quality of products will be analyzed using Aiken's V having a value ranging from 0 to 1. The data on the reliability of electric circuit interpretation ability test instrument will be analyzed using the information function and Standard Error Measurement (SEM). Meanwhile, pretest-posttest data on the electric circuit interpretation ability were analyzed using GLM Mixed Design test. Prior to that, prerequisite test which are data normality and data homogeneity test were conducted before the GLM Mixed Design test.

Validity and Reliability

The product instrument quality was arranged based on a Likert scale ranging from 1-5 which has been validated by 9 experts judgement. Once validated by 9 experts judgement, it was then analyzed using Aiken's V in the range of 0 to 1. The result is a quality and WEIEC product improvement based on assessment by the experts. After the WEIEC application was revised based on experts judgement assessment, WEIEC application is tested on 35 students of SMA 5 Samarinda Class XII Science to assess the quality of WEIEC application that has been revised before applying it to the actual testing. The results of the validation of the WEIEC product application quality assessment based on the experts judgement can be seen in Table 5.

Table 5. Expert Judgement Aiken's V Score on the Quality of WEIEC Application

Validity	Aspect	Aiken's V
Material	Material	0.78
	Worked Example	0.82
	Language	0.81
	Presentation Material	0.81
	Mean Score	**0.80**
Media	Display	0.83

Software Engineering	0.77
Mean Score	**0.80**

Table 6. Aiken's V Score Obtained on the WEIEC Application Quality by the Students

Aspect	Aiken's V	Mean Score
Software Engineering	0.79	
Language	0.81	0.81
Learning	0.80	
Contents of Material	0.83	
Comprehension	0.82	

Table 5 shows that Aiken's V score on the validity of the materials and validity of the media quality of WEIEC application is 0.80. According to Aiken (Saifuddin Azwar, 2011: 134), the range of Aiken's V that is declared feasible is between 0 to 1.00. In other words, it can be said that the score 0.80 can be interpreted as a very good coefficient for the item so it can be concluded that the WEIEC application has very good quality and is feasible to use in learning physics, according to the experts judgement assessment.

Meanwhile, product quality assessment results based on the assessment of 35 students in the preliminary field testing can be seen in Table 6.

Table 6 shows that the mean score of Aiken's V on the WEIEC application quality by the students in the preliminary field testing was 0.81. According to Aiken (Saifuddin Azwar, 2011: 134), the range of Aiken's V that is declared eligible is between 0 to 1.00. In other words, it can be said that the score 0.81 can be interpreted as a very good coefficient for the item so it can be concluded that the WEIEC application is feasible to use and can be applied in the main field testing

After the WEIEC application validity is fulfilled, the next step is to measure the reliability level of the test items on electric circuit interpretation ability. There are 10 items on the electric circuit interpretation ability which were tested on 260 students at SMAN 1 Samarinda before the main field testing was conducted. The analysis of reliability of the electric circuit interpretation ability using information function and SEM is presented in Figure 3.

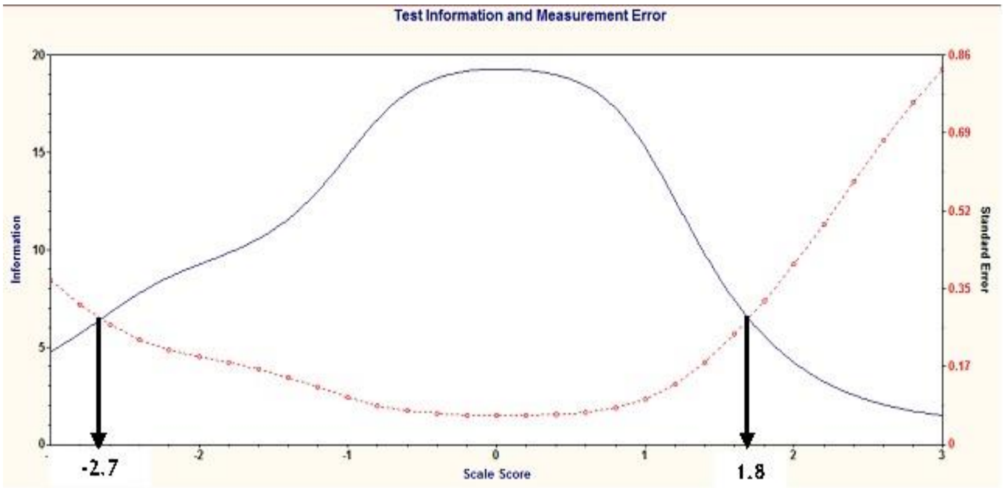

Figure 3. Information Function Graph and Standard Error Measurement (SEM) on the electric circuit interpretation question item

Figure 3 shows information that the electric circuit interpretation ability test is suitable for students with lower to moderate ability levels, which is $-2.7 \leq \theta \leq 1.8$.

Results

Main field testinging was conducted in SMA Negeri 5 Samarinda, East Kalimantan. The research was conducted by dividing the two classes into two groups: the experiment group and the control group. The obtained research results data consist of two things: (1) Data on the Results of electric circuit interpretation ability improvement in experiment-control classes, and (2) WEIEC Application Development Result. Data result on the electric circuit interpretation ability improvement were analyzed using GLM Mixed Design Test

Descriptive Analysis for the Electric Circuit Interpretation Ability Improvement

The data from pretest and posttest of the electric circuit interpretation ability can be seen in Table 7.

Table 7. Descriptive data of the electric circuit interpretation ability

Component	Group	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Pretest	Experiment	20.00	70.00	47.56	14.42
	Control	20.00	68.00	45.35	13.28
Posttest	Experiment	56.00	98.00	76.37	9.64
	Control	38.00	92.00	70.00	13.12

Table 7 shows that the pretest reveals different average score between the experiment class and control class ($\bar{X}_C = 45.35, \bar{X}_E = 47.56$) with $\bar{S}_C = 13.28, \bar{S}_E = 14.42$. On the other hand, the posttest obtains that the average score between the experiment class and control class is experimental class and control class is $\bar{X}_C = 70.00, \bar{X}_E = 76.37$ dengan $\bar{S}_C = 13.12$, $\bar{S}_E = 9.64$. The value amount of the standard deviation in both groups show a variation of improvement of the mathematical representation ability and the electric circuit interpretation which means that there is a subject experiencing a small improvement and there is a subject experiencing a huge improvement.

The gathered data were analyzed using GLM Mixed Design. Before the data were analyzed by GLM mixed design, the data normality were tested with Shapiro-Wilk and homogeneity test with Levene's Test at the 5% significance level. The normality test result of the electric circuit interpretation ability test can be seen in Table 8.

Table 8. Data Normality Test Results

Component	Group	*Shapiro-Wilk*		
		Statistic	*df*	*sig*
Pretest	Experiment	0.949	37	0.093
	Control	0.952	37	0.112
Postest	Experiment	0.969	37	0.379
	Control	0.953	37	0.122

Table 8 shows that the sig score on the electric circuit interpretation ability data in both groups is greater than 0.05 ($p > 0.05$), so it can be concluded that the data were normally distributed. Results of data homogeneity test based on levene's test can be seen in Table 9.

Table 9. **Data Homogeneity Test Results**

Component	Levene Statistic	Sig
Pretest	1.962	0.166
Postest	3.263	0.075

According to Table 9, the sig score in both groups was $p > 0.05$, indicating that the data variance of both groups was the same. If the data have been declared normal and homogeneous, then the subsequent analysis is using GLM mixed design. The purpose of using GLM mixed design test is to test two hypotheses: (1) the hypothesis to determine the interaction between pretest-posttest with the experiment-control groups, (2) the hypothesis to determine the significance of the score change of pretest-posttest with experiment-control group at significance level of 5 %.

The interaction between pretest-posttest with the experiment-control groups can be seen in the output data result of Test of within-Subjects Effect in Anava mixed design shown in Table 10.

Table 10. Test of Within-Subjects Effect

Source		Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
time*group	Greenhouse-Geisser	160.243	1.000	160.243	4.524	0.037	0.059

Table 11. Pairwise Comparisons

Group	(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval for Difference	
						Lower	Upper

						Bound	Bound
Control	Pretest	Postest	-24.649	1.384	0.000	-27.407	-21.890
	Postest	Pretest	24.649	1.384	0.000	21.890	27.407
Experiment	Pretest	Postest	-28.811	1.384	0.000	-31.569	-26.053
	Postest	Pretest	28.811	1.384	0.000	26.053	31.569

Based on Table 10 the sig score of <0.05 indicates that there is an interaction between time (pretest-posttest) and group (experiment-control). This interaction shows that the pretest-posttest scores change on the electric circuit interpretation ability on both groups were significantly different. As for the significance of the pretest-posttest score change of the experiment-control group could be seen in the output data result from Pairwise Comparisons in GLM mixed design shown in Table 11.

According to Table 11, the obtained sig score of <0.05, indicating that the pretest-posttest score change in the experimental group was significant (MD = -28.811, p <0.05), as in the control group (MD = -24.649, p <0.05). The score changes showed that the mobile learning based WEIEC application is effective in improving the students' ability of interpreting the electric circuit. The amount of the effective contribution given by the mobile learning based WEIEC application to improve the ability of interpreting the electric circuit can be seen in the output result of Multivariate Tests on the Partial Eta Squared part shown in Table 12.

Table 12. Multivariate Test

group		Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Experiment	Wilk'S Lambda	0.142	433.577	1.000	72.000	0.000	0.858

Table 12 shows that the amount of effective contribution given by the mobile learning based WEIEC application to improve the electric circuit interpretation ability is 0.858 or 85.8%. Interactions arising between the experiment-control group can be seen in the output graph of Estimated Marginal Means on the GLM mixed Design output as shown in Figure 4.

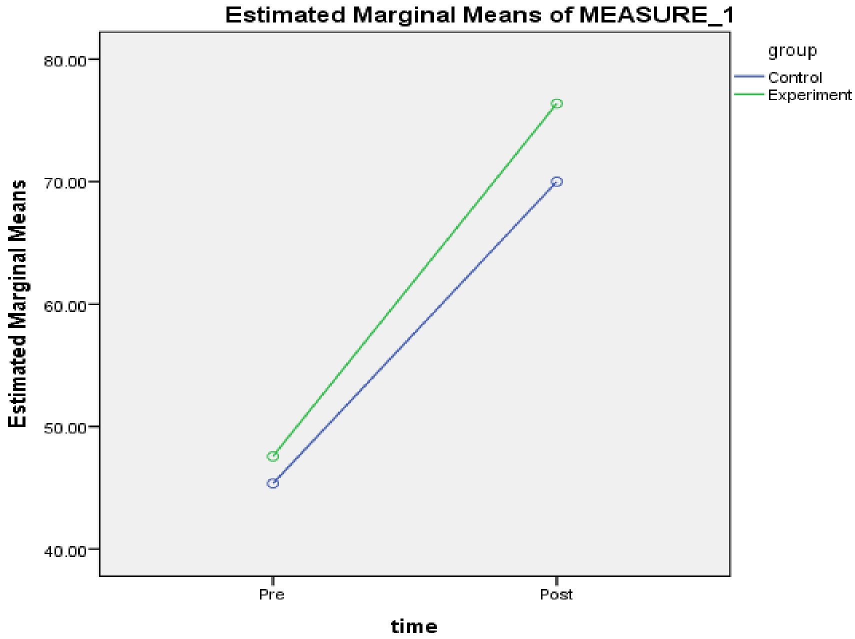

Figure 4. *Output* Graphic of Estimated Marginal Means on the GLM Mixed Design

Figure 4 shows that the students' improvement in their ability of interpreting the electric circuit in the experiment group was greater than in the control group. The graph also shows that there is no interaction between the experiment group and the control group. No interaction showed no influence caused by the control group to the experiment group nor by the experiment group to the control group.

Development Result of Mobile Learning Based WEIEC Application

The visual appearance of components contained in the mobile learning based WEIEC application on the direct current circuit materials among others are: (1) The initial view on the WEIEC opening menu, containing Yogyakarta State University logo, the name of the application, the developer name, and a button menu to the next layer, the exit button to exit the application, followed by the main menu, and contains several menus and buttons. The hint button contains instructions in using the WEIEC application, profile button contains the developer profile. The initial display of WEIEC application can be seen in Figure 5.

Figure 5. Initial Display of mobile learning based WEIEC Application

2) Main menu display, containing the materials menu, the worked example menu, the evaluation menu, the hint menu, the exam menu, and the profile menu as shown in Figure 6.

Figure 6. Main Menu Display of mobile learning based WEIEC Application

3) Materials menu, containing description of the materials that will be learned. Display of the materials menu is divided into sub material parts. To view each of the desired materials, simply click on the materials. The home button functions to return to the main menu as shown in Figure 7.

Figure 7. Materials Menu Display of mobile learning based WEIEC Application

4) Worked example menu, containing 34 examples of problems, which are arranged based on the level of question and the solution. Display of the worked example menu is divided in sub material parts as shown in Figure 8.

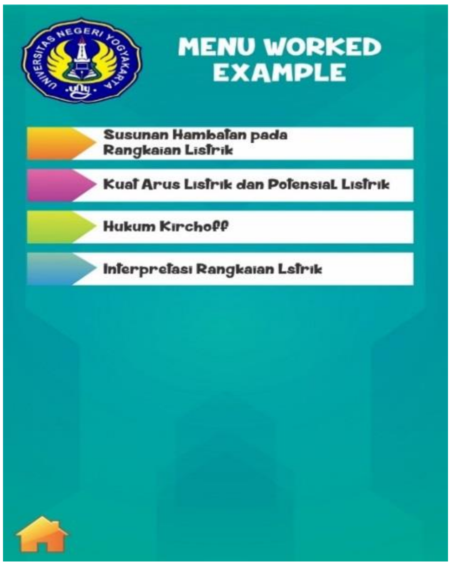

Figure 8. Worked Example Menu Display of mobile learning based WEIEC Application

5) Evaluation menu, containing exercises. Evaluation menu contains 10 short answer questions which are set not to proceed to the next step if the students answer incorrectly. It is shown in Figure 9.

Figure 9. Evaluation Menu Display of mobile learning based WEIEC Application

6) Exam menu, containing additional independent test questions for students which contain 12 essay questions consisting of mathematical representation and electric circuits interpretation as shown in Figure 10.

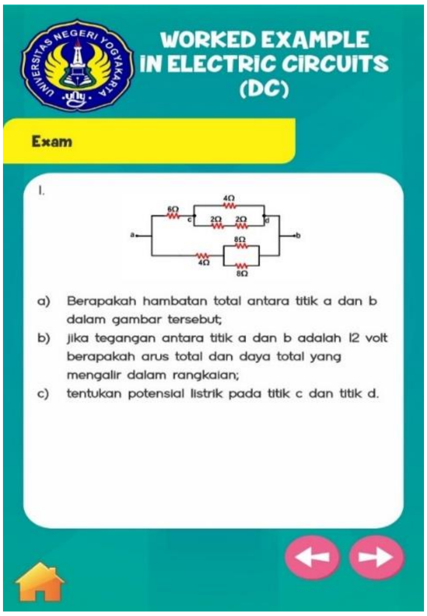

Figure 10. Exam Menu Display of mobile learning based WEIEC Application

Conclusion

Based on the results of research and development, it can be concluded that the developed mobile learning based WEIEC Application has good quality and is feasible to use with the Aiken's V average score by expert judgement of 0.80 on the media feasibility and materials feasibility, and obtains Aiken's V score of 0.81 assessed by the students. The developed WEIEC Applications is able to increase the ability of the students in interpreting the electric circuit as proven by the value of Mean Difference (MD) of -28 811 with an effective contribution given of 85.8% based on the Partial Eta Squared. This means that the developed WEIEC application is effective in improving the ability of the high school students in interpreting the electric circuit.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Mitra Yadiannur is a Master of Physics Education, Mathematic and Natural Science Faculty, Yogyakarta State University, Indonesia.

Supahar is a Doctoral of Research and Evaluation of Education, Mathematic and Natural Science Faculty, Yogyakarta State University, Indonesia.

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