Mobile Interactive Multimedia to Assist Prospective Science Teachers Holding Conceptual Understanding in Problem-Solving Electrical Circuits

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Abstract **– This research proposes a mobile interactive multimedia (MIM) system that allows students to interact with various simulations and animations of electrical phenomena and to apply their knowledge to solve problems in electrical circuits. MIM is a tool that enhances the students' conceptual understanding, correcting their misconceptions, and strengthening their problem-solving skills in electrical circuits, according to the students' knowledge type of transition in learning. The MIM was accessible through an Android-based device and was evaluated using a research and development (R&D) method. The Three Tier-Test and Multiple Misconception Revealing Test assessed students' conceptual comprehension and problem-solving ability. The study involved 53 prospective science teachers enrolled in the Electrical and Magnetism course in third-semester; 27 in the experimental group and 26 in the control group. The findings showed that the MIM met the validity, practicality, and effectiveness criteria.**

Therefore, the MIM was a valid, practical, and effective tool for enhancing the students' conceptual understanding, correcting their misconceptions, and strengthening their problem-solving skills in electrical circuits, according to the students' knowledge type of transition in learning.

Keywords **– Electrical circuits, interactive multimedia, misconceptions, problem-solving.**

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1. Introduction

Problem-solving skills are among the most important skills mastered by students in physics [1], especially for those who are preparing to become teachers [2]. This skill requires mental and intellectual processes to identify problems, formulate strategies, and find the best solutions based on accurate data and information to be applied in relatively new and difficult situations [3], [4]. Problem-solving encourages students to think and use relevant theory [5] and requires mastery of the right concepts to solve and find solutions [2]. Knowledge of concepts can be developed through life experiences and learning activities to improve skills in problem-solving. Mastery of one's concept is strongly influenced by the conception one has.

Mastery of concepts is the most important factor in problem-solving and the basis of solving physics problems [5]. Thus, success in learning the concept indicates success in solving problems. Students with a precise and solid understanding of concepts can solve problems well. Conversely, if understanding of the owned concept is inadequate, it will potentially cause misunderstandings and result in failure in solving problems.

The problem-solving skills students possess are still relatively low [7], [8], [6]. Many researchers have identified the causes of problem-solving difficulties in physics, including the failure to establish the meaning and intent of the problem statement and the lack of mastery of proper and sufficient knowledge about structural construction in certain content areas.

Asgari *et al* [9] explained that students still have difficulty understanding physics concepts and tend to experience misconceptions. These misconceptions can interfere with the process of forming student concepts. The results of Sutopo's research [10] showed that misconceptions are one of the causes of student failure in solving conceptual problems. Misconceptions are ideas or knowledge substantially different from scientists' views [11]. It can interfere with students' concept formation processes, hinder the learning process [12], [13], and is one of the causes of students' failure in solving conceptual problems [10].

Based on the initial study in 2021, it was found that prospective science teachers already have an adequate scientific conception of electrical circuit material which includes the concepts of electric current, series circuits, and parallel circuits. When they are faced with solving numerical problems, they can cope with the problems well. However, they fail when faced with solving problems that use circuit representations that are not the same as those in textbooks. The results of this initial study are similar to the research of Widodo *et al.* [14] that found that students immediately switch to various alternative concepts in solving problems depending on the problem. This also aligns with Bao's three type of student's knowledge transition probability in learning [48]. It was further found that based on the results of the Multiple Misconception Revealing Test (MMRT) on electrical circuit material given to prospective science teachers, it was found that there were three types of misconceptions experienced by students, namely type 1 misconception (cannot distinguish serial and parallel principles), type 2 misconceptions (misunderstanding the principles of open and closed circuits, and being unable to distinguish between circuit and parallel principles), and type 3 misconceptions (misunderstanding the principles of open and closed circuits, misunderstood circuit components, and unable to distinguish circuit principles and parallel).

The level of conception in each individual is different, some are held firmly, some are not strong, and some even appear to be fragments of knowledge [15]. These pieces of knowledge can be selected and used when someone is trying to solve the problem at hand [16]. Because basic knowledge and the ability to transfer it are the most important elements in the problem-solving process [17], when the problem is not solved, students will try to solve it by using the same method from previous experience or using a different method. Thus, a way is needed to help prospective teacher students to be able to choose and hold tightly to the right conception in solving problems. Several ways that educators can use are by using cognitive conflict [18], [19], conceptual changes [20] and the use of interactive multimedia virtual labs [21], [22].

In addition, Bao explains tree types of transition of student's knowledge due to learning activities, α-, β-, andγ-type transition [46]. The interactive engagement learning environment frequently aims to create a constructive process, in which students use positive methods to create new understanding and rectify their flawed understanding in light of their prior knowledge. The technique could potentially be damaging. The interactions between accurate and erroneous knowledge can result in beneficial and unpleasant results since students' incorrect knowledge is sometimes challenging to modify [47].

Cognitive conflict is an inconvenience or instability in students' beliefs about the conception they already have. Cognitive conflict is very closely related to conceptual change, namely cognitive conflict can cause conceptual changes that can change misconceptions into scientific conceptions. Conceptual change is needed by students who experience misconceptions. This conceptual change can bring up the ability to think analogically, reasoning, and critical thinking. Thus, students will have a deep understanding.

In learning activities, educators are responsible for providing learning media to help students understand the material well [47]. With technology's rapid progress and development, students are accustomed to using mobile technology (gadgets) anytime and anywhere to access unlimited information and educational resources [23]. Likewise, educators can package practicum activities integrated with mobile learning in the context of physics learning, which cannot be separated from laboratory activities. So, students can access and do learning anytime and anywhere. Based on research conducted by Koretsky *et al.* [24] it is known that virtual laboratory-based physics learning can improve students' misconceptions.

One form of learning media in the form of digital applications that can be accessed using gadgets is Mobile Interactive Multimedia (MIM) [25]. Apart from making it easy for students to access it, MIM also visualizes and presents abstract material to prevent misconceptions [26]. In line with this, Halim *et al.* [27] explained that interactive media facilitates two-way communication and displays more realistic illustrations, so it is very appropriate to use to correct misconceptions. Research related to the use of MIM to overcome misconceptions in the field of physics has been carried out a lot [28]. However, no research has been found that uses MIM to assist prospective teacher students in choosing and maintaining the correct conception of physics when solving problems.

In this study, researchers will develop MIM that can be accessed via an android-based gadget, integrates a PhET virtual lab laboratory, and can encourage prospective science teacher students to determine the right concepts and reflect on them at each problem-solving stage. Based on the description above, this research aims to develop a MIM that allows students to reinforce the right concepts, change inappropriate conceptions, and hold firmly to the concepts that form the basis of solving problems in electrical circuits.

2. Research Method

This study used a research and development (R&D) design referred to Plomp's model, which was carried out through the preliminary, prototyping, and assessment phases. Through the preliminary phase, it was found that prospective science teachers needed to have the right conception (scientific conception) in electrical circuits, but generally they immediately switched to alternative conceptions that were not appropriate if they solved problems that were not in accordance with the textbooks. Through the concept analysis stage, essential concepts of electrical circuits had been mapped and the concepts that possibility cause misconceptions are analyzed.

In the prototyping phases, MIM content feature design was carried out. The contents of MIM were expected to facilitate ways that educators could use to overcome misconceptions, which involved conceptual changes, cognitive conflicts, and the use of the PhET virtual laboratory packaged in MIM. With the features presented and the facilities to try various ways of series and parallel barriers arranged through a virtual laboratory, then recognizing and formulating the essential characteristics (essential concepts) of the circuit, it is hoped that it would cause conceptual changes in students' minds if the previous conception was insignificant and incorrect. The presentation of the concept in MIM was developed using the structure: concept definition, concept essence, and case studies. The main feature of this MIM was to encourage prospective science teachers to determine the right concept and reflect on it at each stage of problem-solving. These features were useful for preventing students from switching to using inappropriate alternative conceptions when solving problems. The developed MIM contained materials on electrical circuits that could be accessed via an Android-based gadget.

The program used in making MIM Electrical Circuits consisted of PowerPoint Presentations (PPT) to design MIM designs. i-Spring was used to convert .ppt files to .html5, whereas, the Website 2 application was used to convert .html5 files to android apps.

In the assessment phase, the developed MIM was then validated by material experts and media experts to determine its level of feasibility. Furthermore, a reliability test was carried out using a percentage of agreement (PA) to measure agreement between validators. The developed MIM is considered suitable for use in learning if the results of the analysis met the valid and reliable categories. MIM trials were developed to find out their practicality and effectiveness. The trial used The Static-Group Pretest-Posttest Design [29]. The test subjects in this study were third-semester prospective science teachers at state universities in East Java, Indonesia, who were programming the Electricity and Magnetism course. There were 27 students in the experimental class and 26 students in the control class. In the control class, students learned about electrical circuits as they had done so far, namely laboratory activities, lecturer presentations, and discussions, as well as practice questions. In the experimental class, students studied electrical circuits as well as in the control class, but the lecturer's presentations used more developed MIM assistance, and the prospective teachers were encouraged to study IM independently.

Understanding of concepts was measured via test instruments using the Three Tier-Test (TTT) method, the Multiple Misconception Revealing Test (MMRT) developed by Widodo *et al.* [14], and numerical problem-solving. TTT was a type of diagnostic test used to identify student understanding of concepts and misconceptions [30]. TTT had three levels, namely: (1) asking prospective teachers' knowledge about the concept of multiple choice, (2) prospective teachers' reasoning from the process of answering at the first level, and (3) asking questions about prospective teachers' beliefs about the answers at the first and second levels. Referring to Arslan *et al.* [31], the mapping criteria are shown in Table 1. The test was used to determine the level of understanding of prospective science teachers regarding the concept of electric current in a circuit, the concept of series and parallel circuits, and solving series and parallel circuit problems.

Table 1. Three Tier Criteria – Test

First Level	Second Level	Third Level	Decision
True	True	Confident	Scientific concept understanding
True	False	Confident	Misconception (positive false)
False	True	Confident	Misconception (negative false)
False	False	Confident	Misconception
True	True	Not Sure	Lucky Guess
True	False	Not Sure	Guess
False	True	Not Sure	Guess
False	False	Not Sure	Lack of Knowledge

Two physics learning experts then validated the tests developed to determine the level of validity and feasibility. Validation was based on assessment criteria, including content, construction, and language. Based on the expert's assessment, it was known that on tests that measured the conception of electric current in a circuit, the questions were stated to be valid. Likewise, the percentage of agreement (PA) for each aspect and the average PA for questions about the concept of electric current in a circuit reached 100%, which indicated that the expert's assessment of the test items was reliable.

Data on student test results were calculated using percentages and analyzed quantitatively descriptively based on the mapping of Table 1. MIM was declared effective if there was a decrease in misconceptions in science teacher candidate students and significant problem-solving after learning activities using MIM that had been developed. For this reason, a post-test median difference test was carried out for each aspect of the electrical circuit using the Mann-Whitney U Test non-parametric inferential test with the help of SPSS 26.0.

The opinions of prospective science teachers regarding the quality of the developed MIM were assessed through a questionnaire. Response questionnaire data were computed using percentages. Then, the standard deviation was calculated to determine the distribution level of prospective science teachers' responses to the statements in the questionnaire.

3. Results and Discussion

In this section, results and discussions are presented to strengthen the research results which are divided into several parts, namely MIM electrical circuits, MIM validity of electrical circuits, responses of prospective science teachers to MIM electrical circuits, conception and problem-solving ability of student electrical circuits.

3.1. MIM Electrical Circuits

The developed MIM electrical circuit was packaged in text, image, and audio-visual-movement formats as an application file (.apk) that could be accessed via an Android platform gadget. The contents contained in MIM electrical circuits included current, series, parallel, and wiring. Each content had sub-content, which consisted of a definition, essence, and case studies. The understanding sub-content described the meaning of the related content, which was complemented by visualization in the form of animation. Likewise, the essence sub-content, which described the important essences of related content and was also equipped with animation. This essence sub-content played a crucial role in strengthening learner conceptions. The case study sub-content contained four animated videos presenting different examples to finalize prospective science teachers' conceptions. It was also equipped with a PhET simulation which prospective science teachers could use to be creative according to the content they had learned. Figure 1 shows the appearance of the Electrical Circuit MIM.

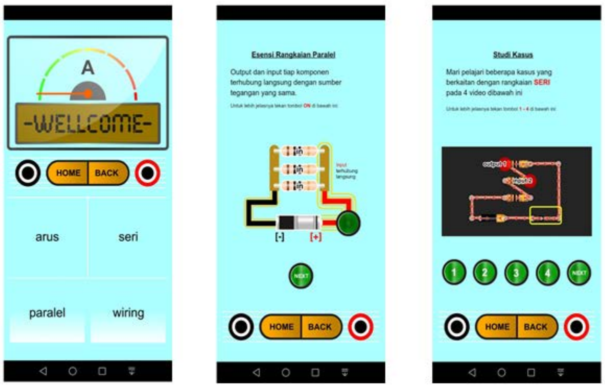
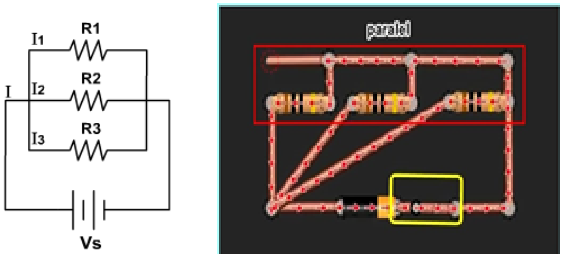


Figure 1. Display of MIM electrical circuits

The main feature of this MIM was to encourage prospective science teachers to determine the right concept and reflect on it at each stage of problem-solving. For this to be achieved, this MIM facilitated ways that educators could use to overcome misconceptions, which involved conceptual changes and interactive multimedia virtual labs. In addition, it also contained ways of solving problems using the right concepts and was accompanied by problem-solving exercises. Conceptual changes could be made by providing contradictory experiences, allowing students to change their existing conceptions with more accurate and scientifically accepted ones.

Research by Widodo *et al.* [14] showed that students had a strong mental picture that parallel circuits were always arranged, as shown in Figure 2 (a). This conception was strongly influenced by textbooks and explanations that so far had used parallel circuit images like Figure 2 (a). This was firmly embedded in the prospective science teachers' cognitive structure, so that it is easier for them to memorize it, and were unable to recognize the essence of parallel circuits, which led to misconceptions. Zulfikar *et al.* [32] stated that students' conceptions were formed based on their learning experiences even though these conceptions were not accepted scientifically.



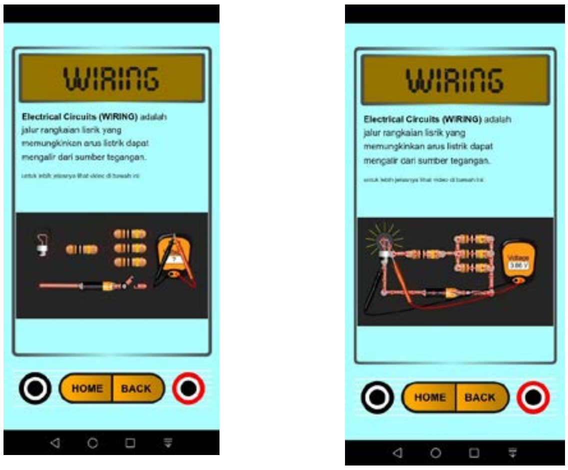
(a) (b)

Figure 2. (a) Parallel Circuits Described in the Book and (b) One of the Parallel Circuit Arrangements in IM Electrical Circuits

The developed electric circuit MIM presented the essence of every content contained in the MIM series. For example, a parallel circuit's essence was that a component's input and output were directly connected to the same voltage source and had more than one current path to carry electric current. Thus, a parallel circuit's essence was not in its components' arrangement. The case study sub-content also reinforced this, presenting four animated videos containing explanations and parallel circuit images. The images were differed from those in the book as well as the explanations they had previously received. Figure 2 (b) is an example of a parallel circuit in the developed MIM. When prospective science teachers learned the essential sub-content and case studies presented in MIM, they realized their misunderstandings. They were willing to develop these conceptions towards correct conceptualization, which might cause conceptual changes to their cognitive structures. Conceptual change effectively overcame, eliminated, and modified misconceptions [9].

As the constructivist theory explains, when students were active in constructing their knowledge, there would be conceptual changes toward concepts that were more detailed, complete, and by scientific concepts [33]. Conceptual change occurred in two stages: assimilation and accommodation. The assimilation stage occurred when students used their conceptions in dealing with new phenomena.

Whereas accommodation occurred when students changed their conception towards a more correct and scientifically acceptable conceptualization. The developed MIM electrical circuit also integrated using the PhET interactive multimedia virtual lab contained in the case study feature. PhET provided simulations on a wide range of topics and practical application of relevant concepts in physics, chemistry, biology, and mathematics. However, the PhET integrated into the developed MIM was only focused on electrical circuits and could be accessed offline. In addition, it made measuring potential differences and currents quicker and easier.



(a) (b)

Figure 3. (a) Component position rules on the problems presented in IM and (b) Problem solving results

Virtual laboratory activities made it easier to master and abstract physics concepts. The findings of several studies showed that the use of a virtual laboratory in learning activities could improve students' understanding of concepts [34], minimize the number of students who experience misconceptions, and reduce the misconceptions of physics education students on the topic of electrical circuits. The developed MIM also contained problem-solving methods using appropriate concepts and was accompanied by problem-solving exercises. Troubleshooting activities were contained in the wiring content. The wiring content explained the electrical circuit paths that allowed the electric current to flow from a voltage source. Wiring content consisted of three sub-contents: definition, essence, and case studies. In the understanding sub-content, besides explaining the meaning of wiring, it was also equipped with an animated video. This animated video presented problems and ways to solve them by adhering to scientifically accepted conceptions. The problem presented in the animated video was assembling a 9-volt battery and four resistors with a resistance of 10 ohms each to turn on a 3-volt bulb with the position rules as shown in Figure 3 (a).

Then, the video also described the stages of solving the problem by paying attention to the essence of series and parallel circuits so that the bulbs in the circuit could light up as shown in Figure 3(b).

To be successful in solving problems, students must be able to understand problems [35], know and use relevant concepts and ways to solve them [1]. In addition, teaching problem-solving strategies during the learning process could also affect students' skills in solving the problems they face [35]. This was because problem-solving was a strategy that was not only related to knowledge but also techniques and procedures [28]. In the essence sub-content, the essences of series and parallel circuits were restated, accompanied by image examples. This was so that the essence of series and parallel circuits could be entered into students' long-term memory. Long-term memory was required so that students may have a solid conceptual basis while developing new advanced concepts and using these concepts to solve problems. Zhan *et al.* [36] explained that when a stimulus was learned repeatedlyit would be remembered better and retained for longer period of time. In the case study sub-content, it was reinforced that there were two things needed to be aware of in the process of solving electrical circuit problems, namely (a) focusing on the type of circuit (series, parallel, or mixed), and (b) focusing on the essence of the connection, not on position. In this sub-content, there were two animated videos containing problems related to wiring and how to solve them, and were also equipped with PhET simulations. Students could use the PhET simulation to free their creativity according to the content they had learned.

3.2. MIM Validity of Electrical Circuits

MIM Electrical Circuits were developed and validated by 3 expert lecturers in physics learning. Table 2 shows the feasibility of MIM Electrical Circuits based on expert validation. The validation results based on criteria content, construction, language convenience and interaction get the percentage of agreement (PA) ≥90% and valid and reliable to use.

Content validity aimed to determine the relevance of the MIM developed with learning materials [37]. The purpose of developing MIM Electrical Circuits was to help prospective teachers overcome misconceptions about electrical circuit material. Assessment of construction criteria was based on four aspects, namely menu and sub-menu links, link navigation, media elements, and attractiveness. In terms of construction criteria, the MIM Electrical Circuits developed were valid and reliable.

The four aspects of the construction assessment received high scores and PA. This assessment showed that the navigation menu contained in MIM functioned very well. The navigation menu was important in operating and making the media more interactive. The developed MIM also presented animated videos that could be interesting and focused on students' attention, as well as strengthen the information presented, making it easier for students to understand the material and could increase students' interest and motivation.

Regarding language criteria, the assessment was based on four aspects: written language, the accuracy of sentence structure, standardization of terms, and consistency of term use. The use of language in MIM Electrical circuits already used good and correct sentence structures, according to rules, consistent and communicative. The linguistic aspect was very influential on the success of learning. The use of language that was good and correct, according to rules, consistent, and communicative would make it easier for students to understand the material.

The assessment was based on user convenience and interactivity on the criteria of convenience and interaction. MIM applications, users were given the flexibility to control the elements in MIM. On the criteria for understanding the concept, three aspects were assessed: the correctness of the concept, the clarity of the concept, and the suitability with the development of science and technology. The high score and PA on this criterion showed that the information presented in MIM is by the material concepts of electrical circuits. Using concepts that were accurate and scientifically acceptable in developing MIM was necessary to avoid misconceptions among students.

The general conclusion from the validators was that the developed MIM Electrical Circuits could be used with minor revisions. The suggestions the validator gave included: (a) it was necessary to add practice questions/reinforcement questions that were relevant and at the same level as the test indicators to be carried out. This was intended to reinforce that MIM Electrical Circuits by design would help prospective science teachers overcome misconceptions about electrical circuits; (b) the presentation of MIM Electrical Circuits was good, apart from that it also displayed a variety of series and parallel circuit models to strengthen the characteristics of series and parallel circuits. These circuits could be further developed into a series model Λ concerning Y or vice versa. Based on the validation results, it could be stated that the MIM electrical circuits developed were valid and reliable for use in learning activities. Valid and reliable MIM could be used as a guide and reference for teachers in carrying out learning.

The use of MIM in learning could be a link between the knowledge possessed by educators and the concepts students would learn, while facilitating the learning of abstract physics concepts. Osman & Lee [38] argued that well-developed and appropriate MIM would positively affect learning activities. Information processing theory states that learning was an internal transformation for individuals resulting from external events in the environment around the individual. MIM's role in this context was as an external event that supports the success of learning.

The use of MIM Electrical Circuits that had been declared valid and reliable was expected to be an external factor that could help prospective science teacher students overcome misconceptions about electrical circuits.

3.3. Responses of Prospective Science Teachers to MIM Electrical Circuits

The response of prospective science teachers to MIM Electrical Circuits about the MIM quality was drawn in Table 2.

Table 2. Prospective science teachers' responses to MIM electrical circuits

	Aspects	Agreement Percentage ± SD (%)
1	The visual of MIM electrical circuits is interesting	96.30 ± 10.48
2	The contents of MIM Electric Circuits are interesting	98.77 ± 6.30
3	Images/animations/videos are easy to understand	100.00 ± 0.00
4	The link on MIM Electrical Circuits works fine	92.59 ± 16.56
5	Audio (narration) can be heard clearly	93.83 ± 12.95
6	The material is easy to understand	97.53 ± 8.73
7	MIM Electrical Circuits presents concepts with proper understanding and can be used to help overcome electrical circuit misconceptions	97.53 ± 8.73
8	MIM Electrical Circuits shows ways of solving problems using the right concepts, accompanied by problem-solving exercises	97.53 ± 8.73
9	MIM Electrical Circuits can help in overcoming misconceptions in electrical circuit material	97.53 ± 8.73
	Average	**96.85 ± 9.02**

Table 2 provides information that the average percentage of prospective science teachers' responses to the MIM of the developed electric circuit was > 90% with a standard deviation of < 13%. The highly positive response from prospective science teachers to the developed MIM showed that they were interested in learning activities using the MIM. In addition, it also showed that the developed MIM was practically used in learning activities. This practicality showed that MIM was easy to operate, helped in the learning process, strengthened student concepts, and was suitable for use by students in learning activities. In line with this, *Rajendra et al* [50] revealed that learning devices that met practicality criteria indicated that these devices were attractive and easy to use in learning. On the other hand, using technology in learning could take place effectively if students could learn comfortably.

Thus, they were able to develop their abilities and understanding of the material being studied [51]. Practical Electrical Circuit MIM would help prospective science teachers overcome misconceptions about electrical circuit material. This MIM was developed to help prospective science teachers overcome misconceptions about electrical circuits.

3.4. Conception and Problem-Solving Ability of Student Electrical Circuits

This study involved two classes: class A as the experimental class and class B as the control class. Tests were given before and after students participated in learning activities. Table 3 shows the analysis of the test results for the two classes.

Table 3. Results of test analysis in the experimental class and control class

Concepts or Problem Solving Skills	**Category**	**Experiment Class**				**Control Class**			
		Pre-test		**Post-test**		**Pre-test**		**Post-test**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Open and closed circuit	Scientific Conception	18	66.67	23	85.19	17	62.96	17	62.96
	Misconception	8	29.63	0	0.00	3	11.11	2	7.69
	Lucky Guess	0	0.00	0	0.00	3	11.11	4	11.11
	Lack of Knowledge	1	3.70	4	14.81	3	11.11	3	11.11
Electric current in the circuit	Scientific Conception	7	25.93	21	77.78	6	22.22	11	40.74
	Misconception	16	59.26	4	14.81	12	44.44	12	44.44
	Lucky Guess	2	7.41	2	7.41	3	11.11	0	0.00
	Lack of Knowledge	2	7.41	0	0.00	5	19.23	3	11.11
Series circuit identification	Scientific Conception	10	37.04	25	92.59	24	92.31	21	80.77
	Misconception	9	33.33	1	3.70	1	3.85	4	15.38
	Lucky Guess	3	11.11	1	3.70	1	3.85	1	3.85
	Lack of Knowledge	5	18.52	0	0.00	0	0.00	0	0.00
Current and voltage in series circuits	Scientific Conception	10	37.04	19	70.37	3	1.09	11	42.31
	Misconception	9	33.33	7	25.93	13	50.00	12	46.15
	Lucky Guess	3	11.11	0	0.00	3	11.54	0	0.00
	Lack of Knowledge	5	18.52	1	3.70	7	26.92	3	11.54
Parallel circuit identification	Scientific Conception	18	66.67	26	96.30	14	53.85	21	80.77
	Misconception	9	33.33	0	0.00	11	42.31	4	15.38
	Lucky Guess	0	0.00	1	3.70	1	3.85	1	3.85
	Lack of Knowledge	0	0.00	0	0.00	0	0.00	0	0.00
Current and voltage in parallel circuits	Scientific Conception	5	18.52	20	74.07	4	15.38	13	50.00
	Misconception	11	40.74	6	22.22	10	38.46	11	42.31
	Lucky Guess	0	0.00	0	0.00	1	3.85	0	0.00
	Lack of Knowledge	2	7.41	1	3.70	11	42.31	2	7.69
Problem Solving with MMRT on parallel circuit	Scientific Conception	0	0.00	25	92.59	0	0.00	19	73.08
	Misconception	15	55.56	1	3.70	25	96.15	6	23.08
	Lucky Guess	0	0.00	1	3.70	0	0.00	1	3.85
	Lack of Knowledge	12	44.44	0	0.00	1	3.85	0	0.00
Numerical Problem Solving on parallel circuit	True	11	40.74	24	88.89	13	50.00	14	53.85
	False	16	59.26	3	11.11	13	50.00	12	46.15
Problem Solving with MMRT on serial circuit	Scientific Conception	1	3.70	26	96.30	11	42.31	20	76.92
	Misconception	14	51.85	0	0.00	2	7.69	5	19.23
	Lucky Guess	0	0.00	1	3.70	4	15.38	1	3.85
	Lack of Knowledge	12	44.44	0	0.00	9	34.62	0	0.00
Numerical Problem Solving on serial circuit	True	13	48.15	22	81.48	17	65.38	15	57.69
	False	14	51.85	5	18.52	9	34.62	11	42.31
	Total	27	100	27	100	26	100	26	100

To find out the significance of the differences in the post-test between the two classes, a two-party scientific understanding different test was carried out in the group with a significance level of 0.05. Table 4 depicts a summary of the results.

Table 4. Summary of difference test results in two classes

	SC_el_cir	MMRT	Num_PS
Mann-Whitney U	229.500	244.000	230.000
Wilcoxon W	580.500	595.000	581.000
Z	-2.267	-2.607	-2.437
Asymp. Sig. (2-tailed)	.023	.009	.015

Based on Table 4, there were significant differences between the experimental and control classes in the concepts of electrical circuits, MMRT, and numerical problem-solving. Based on the data and analysis, it appeared that, in general, the class that used MIM Electrical Circuits had a better scientific conception than the control class. In other words, the MIM Electrical Circuits developed could help prospective science teachers select and maintain the correct conception of physics when solving problems. The success of MIM Electrical Circuits in assisting prospective science teachers in overcoming misconceptions about electrical circuits was supported by several factors, namely MIM's features that facilitated conceptual changes, the presence of animated videos and scaffolding in solving problems accompanied by examples of their solutions, as well as PhET simulations on sub-content case studies that prospective science teachers could use to be creative according to the concepts they had learned. This was by students' opinions (Table 2) that MIM content was interesting, easy to understand, helpful in overcoming misconceptions about electrical circuit material and giving ways of solving problems using appropriate concepts, accompanied by problem-solving exercises. The MIM Electrical Circuits developed were equipped with animated videos in order to present visible learning, so that learning became very real, and easy for students to understand and remember [56]. On the other hand, using MIM was very useful in visualizing concepts [57]. By using MIM, students could see symptoms, interact, and see a real picture of a concept [58].

Based on Table 3, in general, the prospective science teachers' scientific conception understanding became better after the learning process was undertaken, both in the experimental and control classes. Even so, the percentage of prospective science teachers' scientific conception understanding in the experimental class was greater than in the control class.

In the open and closed-circuit concept, there was a shift to scientific conception understanding in the experimental class from 66.67% to 85.19%, while in the control class, it was stagnant at 62.96%. A similar trend occurred in electric current in the circuit, series circuit identification, current, and voltage in series circuits, parallel circuit identification, current and voltage in parallel circuits, problem-solving with MMRT on the parallel circuit, numerical problem-solving on the parallel circuit, problem-solving with MMRT on serial circuits, as well as numerical problem solving on serial circuits. MIM learning activities presented a new educational atmosphere. Apart from making it easier for educators to convey material, it also facilitates student activity, so that learning takes place more effectively. MIM presented learning content in a more representative and interactive content, so that it could help students develop their knowledge, skills, and understanding [39]. MIM integrated various content such as text, animation, simulation, and virtual laboratories that could be operated interactively [40]. The research found that 100% of prospective science teachers agreed that images/ animations/ videos were easy to understand and 93.83% agreed that audio (narration) could be understood clearly. The use of these contents packaged in MIM could function as a liaison between prospective science teachers' conceptions and the new concepts they received so that they could assist students in developing their scientific conceptions.

MIM Electrical Circuits was equipped with PhET simulation features that could be accessed offline. This feature was contained in the case study sub-content which students could use to be creative according to the concepts they had learned. prospective science teachers who were allowed to interact by directly simulating their knowledge would be able to understand the concept better than those who were only observing. The study results showed that using simulation in learning effectively overcame misconceptions about electrical circuits [52]. When prospective science teachers' scientific conceptions related to electric current in the circuit, problem-solving with MMRT on parallel and problem-solving with MMRT on serial circuits developed, their scientific understanding would automatically increase and their misconceptions would decrease. Thus, the use of MIM Electrical Circuits had contributed significantly to students' mastery of concepts, so that it greatly assisted students in reconstructing their knowledge.

Conversely, according to the students, enjoy learning with mobile interactive multimedia.

Several students' quotation related to the intervention in this study state: "Mobile interactive multimedia helped me to visualize the concepts of electrical circuits and apply them to solve problems." - Student #05

"I enjoyed learning with mobile interactive multimedia because it was engaging. It also gave me feedback and hints when I was stuck." - Student #20

"The application was useful in enhancing my conceptual understanding of electrical circuits. It challenged me to think about the solution of the problem." – Student #27

Based on these students' opinions after the intervention, MIM can facilitate the student's knowledge transition toward the substantive and procedural concept by providing interactive and engaging learning experiences [48],[49].

MIM also succeeded in facilitating prospective science teachers in improving their ability to solve numerical problems related to electrical circuits. In Numerical Problem Solving on the parallel circuit, there was an increase in the percentage of prospective science teachers who could do the questions properly and correctly, from 40.74% to 88.89%. There was also an increase in the control class, but the increase was only 0.38%, from 50.00% to 53.85%. Likewise in numerical problem-solving on serial circuits, there was also an increase in prospective science teachers who could do the questions properly and correctly, from 48.15% to 81.48%. Whereas in the control class there was a decrease in the percentage of prospective science teachers who could answer the questions properly and correctly, from 65.38% to 57.69%. This showed that MIM could not facilitate the improvement of numerical problem-solving skills.

The ability of numerical problem-solving skills involved the use of skills in calculating operations in mathematical calculations. This ability was very important to be mastered by prospective science teachers in learning physics because it greatly influenced the ability to solve problems that involve mathematical calculations. Redish [41] explained that the purpose of learning physics was for prospective science teachers to be able to apply mathematical models (equations) that could be used to predict and explain physical phenomena. The validator declared valid based on the validation results on the content criteria, which included an assessment of practicing problem-solving methods using the right concepts. Based on prospective science teachers' response questionnaires, it was found that 97.53% of them agreed that the MIM Electrical Circuits developed showed ways of solving problems using the right concepts, accompanied by problem-solving exercises.

Packaging examples and problem-solving strategies in MIM had an impact on increasing prospective science teachers' numerical problem-solving skills.

As Csíkos & Szitányi [42] revealed, teachers agreed that problem-solving strategies must be taught explicitly. On the other hand, Barham [53] explained that educators must choose appropriate problem-solving strategies to develop prospective science teachers' problem-solving skills. Teaching problem-solving strategies qualitatively, besides increasing the understanding of the concepts and principles of physics that underlined them, might also increase student achievement. Quantitative problem-solving strategies could improve prospective science teachers' numerical problem-solving skills. The Electrical Circuit MIM developed also included ways to solve problems using the right concepts and was accompanied by problem-solving exercises. The problem-solving exercise was presented in a form of scaffolding provided by the lecturer. Educators could provide scaffolding to increase student's understanding until they were independent in achieving their goals. On the other hand, providing problem-solving exercises related to everyday life was also useful in fostering curiosity and training to generate various creative ideas [54].

In addition to increased understanding and better problem-solving compared to the control, experimental class students could provide explanations by analogy. For example, in the MMRT series circuit, students provided an analogy explanation of why they drew the circuit the way it does. These explanations were, for example, 1) in a series circuit, the resistances were arranged side by side, it was like the right hand of the resistance coupled with the left hand of the other resistance, and the remaining hand was connected to the voltage source; 2) a series of hands holding each other holding one up; 3) in a series circuit, the resistances R_1, R_2, and R_3 would be connected, the input of one resistance would be connected to the output of another resistance. Analogies relate unfamiliar formulas, processes, or concepts to those more familiar to the individual based on previous experience. Thus, new knowledge was created mentally by establishing connections between existing and new individual schemata. The capacity to explain by analogy enabled to transfer the knowledge from previously solved problems to new problems. Analogical thinking in solving problems involved thinking skills to correlate the knowledge possessed with the problem to be solved. Analogies could increase students' learning motivation while still considering concepts from other points of view [43]. The ability to make analogies showed more meaningful learning and could increase the retention of difficult concepts for students to understand [44].

The analogy thinking process could be representation, arrangement, mapping, application, and verification [45]. Analogical thinking in problem-solving required a cognitive process in mapping between problems, sources, and target problems [44]. The ability to provide explanations using analogies made by students showed that the developed MIM provided in-depth and meaningful learning for students. Meaningful and in-depth learning was high-level thinking involving active intellectual use and constructing meaning through pattern recognition and concept association [55].

4. Conclusion

The developed Electrical Circuit MIM meets the aspects of validity, practicality, and effectiveness. On the aspect of validity, the experts state that the criteria for content, understanding of concepts, language, convenience, and interaction are valid. In the practical aspect, prospective science teachers convey a positive response to the Electrical Circuit MIM that has been developed with assessments that tend not to spread. Likewise, the aspect of effectiveness appears that the class that uses MIM Electrical Circuits has better scientific conception and problem-solving skills than the control class. Thus, it can be concluded that the MIM Electrical Circuits developed are valid, practical, and effective in helping prospective science teachers to reinforce appropriate concepts, change inappropriate conceptions, and hold firmly to the concepts that form the basis of problem-solving in electrical circuits. However, these limits and obstacles must be addressed in future research. First, the sample size and length were both small and short, limiting the findings' generalizability. Second, because the system was only evaluated on one topic (electrical circuits) and one domain (physics), its applicability to other topics and domains may be limited. Third, the system relied on a mobile device, which may offer technical and logistical challenges in particular situations. Fourth, the system did not provide adaptive and personalized learning paths for various learners, which may have impacted motivation, performance, and their deep and rigorous understanding based on substantive and procedural concepts in science. Future research can focus on changing conceptions when using MIM, by thinking aloud when studying MIM.

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