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DESIGN OF EXPERIMENTAL PROBLEM SOLVING-BASED LEARNING PROGRAM TO IMPROVE MENTAL MODEL AND TO ENHANCE MENTAL-MODELING ABILITY

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ABSTRACT

Research on developing experimental problem solving-based learning program to overcome the low mental model (MM) and mental-modeling abilities (MMA) physics teacher candidate in one of the college teachers in Palu have been conducted. Mental model construction is the “core” of meaningful learning and along with MMA (modeling) become a keyword to understand the key concepts in the science learning. The development of this learning program was using R & D method. Development process from requirement analysis phase until implementation process has already been described using 4D model: define, design, develop and disseminate. The subject matter of this research was the Basic Physics II course on the topic of electricity and magnetism. Based on the data analysis and findings at each stage of development, it is concluded that the learning program stages which have improved MM and also enhanced the MMA of physics teacher candidates consist of learning orientation phase; orientation to the problem; pre-experimental brainstorming; experiment; evaluation; as well as the phase of reinforcement and follow-up.

ABSTRAK

Penelitian tentang pengembangan program berbasis eksperimen problem solving untuk mengatasi rendahnya mental model (MM) dan mental-modeling abilities (MMA) calon guru fisika di salah satu guru perguruan tinggi di Palu telah dilakukan. Konstruksi model mental adalah inti dari pembelajaran yang bermakna dan bersama dengan MMA (pemodelan) menjadi kata kunci untuk memahami konsep-konsep kunci dalam sains. Pengembangan program pembelajaran ini menggunakan metode R & D. Proses pengembangan dari tahap analisis kebutuhan hingga proses implementasi dijelaskan menggunakan model 4D: define, design, develop, disseminate. Materi yang dikaji dalam penelitian ini adalah mata kuliah fisika dasar 2 tentang topik listrik dan magnet. Berdasarkan analisis data dan temuan pada setiap tahap perkembangan, disimpulkan bahwa tahapan program pembelajaran yang telah memperbaiki MM dan juga meningkatkan MMA calon guru fisika terdiri dari fase orientasi pembelajaran; orientasi pada masalah; pra-brainstorming eksperimental; percobaan; evaluasi; serta fase penguatan dan tindak lanjut.

Keywords: Course Program; Mental Model; Mental-Modeling Ability (MMA); Problem Solving Laboratory

INTRODUCTION

Mental models and mental modeling abilities are two important factors in the problem solving process (Mansyur, 2010; Wang, 2007; and Tallman and Henderson, 1999). Mansyur (2010), reported that the higher the academic level of a person, the better the mental model and the higher the ability to solve problems. This means that a person’s mental model is dynamic can change with increasing learning experience (Corpuz & Rebello, 2011) and context dependent (Didiș, N., et al, 2014). A good

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mental model has been constructed from links between elements of the problem description and underlying knowledge (Mansyur, 2010).

The process of understanding how the system works requires individuals to construct a mental model of the system in their minds. This can be done by building a network of related concepts and understanding the functional relationship of a number of different aspects and levels of the system based on daily knowledge and experience (Vosniadou, et al, 2004). Jansoon, et al, (2009) divides mental model levels into three levels:

Level 1: the model is seen as a “toy” or a “copy” of reality. The model created at this level is not based on concept and only based on experience that cannot explain the problem.

Level 2: the model can lead to goals explicitly and specifically. The model made at this level is based on the concepts and phenomena that are displayed (context) in the problem but cannot be developed.

Level 3: the model has been constructed to develop and test an idea, and can be manipulated and operated against the test. Models at this level are dynamic, can be constructed based on concepts, contexts, and can be developed to solve problems that are seen in the presence of several alternative solutions.

The ability to use or to change mental models while the model used cannot be applied or is inappropriate in the problem solving process is called mental-modeling ability (MMA). According to Wang (2007), high mental-modeling ability (H-MMA) is characterized by the emergence of abilities:

1) Resulting mental models in the form of diagrams or other relevant forms of representation.
2) Being able to reconstruct, manipulate, or adjust the mental model based on propositions or problem conditions.
3) Re-arranging the approach based on the problem.
4) Monitoring the process of explaining and constructing the mental model, as well as
5) Checking and matching mental models and answering problems using an alternative approach if the problem is relatively new.

It is undeniable that the ultimate goal of learning physics is the ability to solve problems (Korsunsky, 2004). Likewise on the standard of higher education learning processes that require problem solving competencies for graduates (Kemenristekdikti, 2015). The transition of the problem solver categories of novice to an expert requires an increase in problem solving abilities (Walsh, et al, 2007). This increase is able to be trained through problem-based learning (Komariah, K., 2011; Tallman & Henderson, 1999). The results of the research by Supriyatman, et al (2014) on physics education students of one of the state universities in the Central Sulawesi in the second and fourth semester who were attending the Basic Physics II and Magnetic-Electricity courses, showed that the low level of students’ mental models in the concepts of electricity and magnetism, and even tended to misleading in choosing a concept and experiencing misconceptions.

Based on the results of preliminary studies that have been conducted, it was found that the learning activities do not support the improvement of mental model abilities of students. This fact is quite apprehensive considering they are prospective teachers who will teach these concepts to their students. Therefore, to improve the ability of students’ mental models, especially in electricity and magnetic topics, it is necessary to design learning programs that can train students to solve problems regarding with the topics systematically. One of the methods utilized is hands on and minds on activities. By using hands on and mind on activities, students are able to be trained to solve problems, increase their learning experience and are able to use less energy in accessing and organizing cognitive elements.

METHOD

This research is a research and development research (R & D) of 4D model (define, design, develop and disseminate) from Thiagarajan, et al (1974) to develop Basic Physics II courses on electricity and magnetism concepts that is able to improve mental models and to enhance the MMA of physics teacher candidates. The preliminary step of this research were initial investigating to the students’ mental model and MMA profile on electricity and magnetic concepts (Supriyatman, et al., 2014); to analyze the curriculum documents, lesson plan (SAP), and final test documents. At the design stage, based on the results of the mental model analysis, MMA, and the document profiles, the purpose of each step of the development and constructing of the learning program have already been planned.

The learning program carried out was complemented by several instruments, including SAP (lesson plans), LKM (students’ worksheets), PD (lecturers' guidelines) and problem solving tests related to the topics which were studied. The four learning instruments were validated by four physics experts both in terms of content and learning aspects. The results of expert validation are then utilized as the basis for the revision and the revised instruments are then tested. Problem solving in addition to expert validation was also carried out field validation.

To obtain field validation, the draft of the problem solving test was tried out to 49 second semester students who had attended electricity and magnetism lectures. Furthermore, based on the results of the validity analysis, a number of questions were chosen which were ready to be utilized in the study. The next step, SAP, LKM, PD, and problem solving tests are implemented in Electricity and Magnetism learning which is attended by 33 students in the fourth semester. The research data at this phase have already been analyzed and utilized as a consideration to revise the draft program and the instrument (develop-phase). The results of the revision of this phase are then re-validated. Furthermore, to determine the effectiveness of learning programs that have been designed, revised research instruments are then implemented to the 29 students participating in the Basic Physics II lecture on the concept of electricity and magnetism (disseminate phase).

Learning indicators of successful program implementation are determined from a minimum of 75% of respondents (lecturers and students) who agree and strongly agree and the improvement of mental models, MMA and problem solving scores. The instruments utilized to collect data were students' response sheets, lecturers' response sheets, Electricity problem solving tests, and Magnetism problem solving tests. In problem solving tests, the methods of data collection utilized were three ways, namely traditional tests (paper and pencil test), thinking aloud, and semi-structured interviews to explore the consistency of student answers, especially in determining mental models and MMA.

RESULTS AND DISCUSSION

Define phase

Document analysis results in the define phase show that SAP and experiment instructions are still traditional learning, the learning carried out still uses the pattern: Lecture - Exercise - Assignment. Experimental guidance are still in the form of cook-books and separate from supporting courses. Exam questions for students are also rarely found using a form of problem solving tests.

Design phase

The learning program has ever been developed consists of learning tools: lecture models as learning process syntax contained in the learning implementation of lesson plan (SAP), student learning guides contained in student worksheets (LKM), lecturer guidelines (PD) as lecturer guidelines in guiding student learning and problem solving tests as an instrument to conduct an assessment in exploring mental models, mental-modeling ability (MMA) and problem solving abilities.

The learning model developed is a problem solving based lecture model based on the Simanjuntak's framework (2012) which is used to improve meta-cognition skills. The application of this model is able to improve student cognition and meta-cognition on the topic of Kinematics and Dynamics in the medium category (Mariati, et al, 2017). This model consists of five phases: Phase 1 Orientating students on problems; Phase 2 Organizing students to study; Phase 3 Guiding a problem-solving based investigation individually and in groups, Phase 4 Developing and presenting the results of the investigation, Phase 5 Strengthening and following-up to learning. The part developed in this research is to include the process elements in the formation of mental models in Phase 3 by adding a POE strategy (predict, observe and explain). This strategy has been utilized by Wang (2007) and Khanthavy (2012) to investigate students' mental models. These phases and the activities of lecturers and students in each phase are stated in SAP.

Experiments conducted in this study using real lab and virtual lab. Real lab is used in experiments that require real observation (can be observed by the five human senses), whereas in experiments that require observation of abstract quantities, a virtual lab have been used. According to Zacharia and Anderson (2003), understanding the concept of students on the abstract concept by experiment using a virtual lab is higher than that of students who use real labs. This program is designed in nine-meetings with three lecture units (three credits), with a composition of seven lectures and two exams.

The students' activity sheet (LKM) developed has been adapted from the models of

Heller, Keith, and Anderson (1992) which featured nine steps of problem solving strategies in solving physics problems experimentally: (1) questions (real-world problems); (2) equipment; (3) prediction; (4) method questions; (5) exploration; (6) measurement; (7) analysis; (8) evaluation and (9) conclusions. Topics displayed in this problem solving consist of seven topics, that are; electric charge, capacitors combination, switch and lamp combination, RC circuit, voltmeter, induction emf, and generator.

Lecturer's guidelines (PD) have been developed referring to the LKM that have been made. PD as a lecturer guide was used to conduct problem-based experiment processes so that the structure follows the structure of the LKM. Basically this PD contains the possibility or alternative answers of students in doing problem solving.

Assessment instruments have been developed referring to the real-world problem of Heller & Heller (1999) in their book of Cooperative Group Problem Solving in Physics. Problem solving tests in the form of rich problem tests, students as problem solvers are required to solve contextual problems using several related concepts. Students should have being the ability to analyze problems, link concepts between contexts, make analogies, and explain using appropriate representations (Gilbert, et al, 2008).

Problem-solving tests (PS) have electricity and magnetism topics that are used differently from essay tests in general, especially in the test instructions. The test instructions are listed: "Do the following questions by giving answers based on your knowledge. Write clearly along with a sketch or picture as an illustration of everything you think about when answering the question on the answer sheet. This guide is written with the intention that researchers can access their mental model as a substitute for thinking aloud.

Develop phase

Model and instrument tests have been conducted on 4th semester students who participated in Electricity and Magnetism courses. The model used consists of 5 phases: Phase 1 Orientating students on the problem, Phase 2 Organizing students for learning, Phase 3 Guiding individual and problem-solving based group inquiry, Phase 4 Developing and presenting the results of investigations, Phase 5 Strengthening and following-up learning. This model has been elaborated in the program tools in the form of SAP and PD as instructors for lecturers and LKM as a guide for students in solving experimental-based problems. Lecture material at the Basic Physics level consisting of four topics on electricity problems and three topics on Magnetism problems planned in seven meetings and two tests. The electricity problem-solving test is carried out after the end of the electricity topic and the Magnetism problem-solving test is carried out after the end of Magnetism topic. Each meeting uses 3x50 minutes which is equivalent to three credits.

This testing phase has aver used one group post-test designed and obtained data about mental models, MMA and problem solving scores as shown in Table 1. Increased problem solving scores (PS) from 16% who had a score above 7 in electricity material to 41% in magnetic material. This can also be seen from the increase in the number of students who experienced MM improvement at level 3 from 6% to 14%, and MMA on H-MMA from 8% to 19%.

Table 1. Recapitulation of program test results

Aspects measured Electricity		Topics/ Number of Students (%)	
		Magnetism	
Level of MM	*NC (%)*	10	15
	Level 1 (%)	59	43
	Level 2 (%)	25	29
	Level 3 (%)	6	14
Categories of MMA	Blank (%)	10	15
	L-MMA (%)	61	29
	M-MMA (%)	21	38
	H-MMA (%)	8	19
Scores of *PS ≥ 75*		16	41

Notes:
NC : not clear (mental model not accessible / answer blank)
Blank : MMA cannot be accessed
% ∆ : Percentage of the number of students who experienced a better change
L-MMA : Low-mental modeling ability
M-MMA : Moderate-mental modeling ability
H-MMA : High- mental modeling ability

In the testing phase although it has described an increase in PS scores, an increase in the number of students who managed to improve MM, and an increase in MMA, but there are still deficiencies in the learning process. These weaknesses include students still having difficulty finding concepts related to problems; and connecting with the problems given to the right solution; and do not conduct evaluation and meta-cognition (Supriyatman, et al, 2018). These findings were then used as material in revising lecture programs based on developed problem solving experiments.

The implementation phase was carried out using the pretest - post-test design method to 29 students participating in the Basic Physics II course. The learning phases carried out are as follows: Phase 1 Orienting students to the learning; Phase 2 Orienting students to problems; Phase 3 Guiding students to pre-experimental brainstorming; Phase 4 Guiding individual- and group- inquiry based on problem solving; Phase 5 Evaluating problem solving results, and Phase 6 Strengthening and following-up learning. These stages are then refined by sharpening the emphasis on MM construction (Phase 3) and the characteristics of H-MMA (Phase 5). The improvement of this stage was able to reaffirm the increase in PS scores, MM improvement, and increase in the teacher's MMA as shown in Table 2.

Table 2 shows that students who have participated in learning programs and problem solving-based experiment experience an increase in problem-solving skills both on the topic of electricity and on the topic of magnetism. This increase is indicated by an increase in PS scores of 38.3% in the topic of electricity and 38.1% in the topic of magnetism. The lecture is able to improve MM students both on electricity topics and on magnetism topics. Students experience MM improvement in the topic of electricity at 58% and 59% on magnetism topics.

The lecture program that was developed has also increased student MMA both on both topics. The increase in student MMA was obtained from the percentage of students who experienced an increase in the MMA category in the post-test results. Students experienced an increase in MMA on the topic of electricity by 63% and on the topic of magnetism by 64%.

The following is an example of improving the level of M25 students' mental models in working on electricity material problem solving tests: Problem: "As a researcher, you are tasked with investigating the electricity properties of metal modifications of your research. Your initial step will be to determine the metal resistivity properties *(ρ)* and for this purpose you prepare two similar metal groups. The first group consists of three metal rods of the same diameter but vary in length and the second group consists of three metal rods with different diameters but the same length. Make predictions from the two

Table 2. Recapitulation of the results of program implementation.

Aspects Measured Pretest		Electricity Topics		Magnetism Topics	
		Posttest	Pretest	Posttest	
Level of MM	NC	13	2	16	7
	Level 1	55	29	51	22
	Level 2	30	52	30	39
	Level 3	2	17	3	32
	%Δ	58		59	
Categories of MMA	Blank	13	2	15	7
	L-MMA	66	35	60	24
	M-MMA	21	44	22	37
	H-MMA	0	19	3	15
	% Δ	63		64	
Problem- solving Scores	Scores	3.5	5.9	3.3	6.9
	N-Gain	38.3		38.1	

Notes:
NC : not clear (mental model not accessible / answer blank)
Blank : MMA cannot be accessed
% Δ : Percentage of the number of students who experienced a better change
L-MMA : Low-mental modeling ability
M-MMA : Moderate-mental modeling ability
H-MMA : High- mental modeling ability

groups of metals, design the steps of the investigation, what data are needed, make a table of observations, and analyze the data.”

Answers to the initial M25 student tests in the level 2 mental model category:

“To investigate the electricity properties of metal modification, the data needed to determine the metal resistivity level *(ρ)* is the length, cross-sectional area, current. Based on this we need to see the current flowing to see the magnitude of metal resistivity. Thus, the metal resistivity which is influenced by the cross-sectional area and the length of the metal rod and the current flowing in the metal rod we can determine the resistivity level.”

The answer to M25 above has shown that the model formed in analyzing problems has used the correct concept. The M23 model has explicitly guided the expected solution. But at the end of the answer, M25 students do not display the form of representation in the form of equations or images that explain or guide in the problem solving process. So that M25 is categorized as MM level 2.

M25 student final test answers:

“After reading the problem first in this case that is to determine the metal resistivity properties *(ρ)* and two similar metal groups are prepared with the first group division of three metal rods of the same diameter but varying in length and the second group consists of three metal rods whose diameter different but the same length. The thing that needs to be done to test is to prepare an electricity measuring device such as a voltmeter and ampere-meter and then we utilized the power supply, the ruler to measure the length and micrometer of the screw and the calipers as other supports. Then we obtained the data needed, namely, the length of the metal rod, diameter, current strength, and stress on the metal rod. In determining metal resistivity *(ρ),* this process has been influenced by two factors, namely the length and width of the conductor or metal. The diameter we obtain is used to calculate the metal cross-sectional area with us assuming a metal cross section is a circle so that $A = \pi r^2$.

Table 3. (for the same diameter and length)

Length (M)	D(m)	A (m^2)
5.10^{-1}	2.10^{-2}	
4.10^{-1}	2.10^{-2}	
3.10^{-1}	2.10^{-2}	

Table 4. (for different diameter and the same length)

Length (M)	D(m)	A (m^2)
2.10^{-1}	5.10^{-2}	
2.10^{-1}	4.10^{-2}	
2.10^{-1}	3.10^{-2}	

It can be seen that for similar materials have “the same metal resistivity”.

The answer to M25 appears to be an improvement in the use of representations in the form of tables and equations used in the problem solving process. The dynamics of the model built by M25 guide him in solving problems. So that M25 in the final test is categorized as MM level 3.

Example of Improvement of MM M23 students on magnetism context number 2. Answer of M23 at MM level 2 at initial test and level 3 at final test:
M23 initial test answer:

“I decided that because, as we know, the compass needle always points towards the north and south which is caused by being attracted by the South Pole and the north pole of the earth’s magnet, which is why I decided to use a compass. Then to determine the magnitude of the magnetic field qualitatively using a compass in my opinion, by using an electric current wire the coil of iron-core wire that is electrified can draw iron and steel. This shows that an electric wire coil can produce a magnetic field. When the electric current flowing in the conveyor is enlarged, it turns out that the compass needle pole deviates even further.”

M23 final test answers:

“In this case I decided to use a compass because the first there was no tool to be used. Then the second, as we know, the earth’s magnetic poles move so slowly that the compass can still function if it is used to measure magnetic fields. Then to determine the magnitude of the magnetic field qualitatively, namely: a compass needle placed in a magnetic field will align its position with the magnetic field line. The North Pole will show the direction of the magnetic field at that point. If the compass needle is moved at the point around the wire that is running, then the compass needle will appear to move in the direction of the tangent to the circle centered on the wire. From the above events it can be concluded that the direction of the magnetic field line due to the current wire is parallel to the tangent lines of the circle centered on the wire with the direction indicated by the compass north pole. There is another way besides using the compass in this case by using the right hand rule."

The final test pattern answer M23 indicate that the thinking pattern constructed by M23 showed an understanding that the field presented by the compass is a magnetic field at the point where the compass is located, using the correct concept with a fairly clear expansion. M23 also builds its mindset by showing alternative solutions that can be developed. M23 is not rigid with the models that have been built at the beginning of problem solving.

Level 3 mental model (MM) category is also shown by M15 and M22 in the context of number 3 magnetic material with the final test answers as quoted below.

M15 final test answers:

"First, speed up the flow of water until it rotates faster we can add the rotor in the generator section, because this rotor is a rotating part of the generator. This rotor consists of a magnetic field that produces magnetic flux. Second, increase the number of coils. It is because when the spinning coil causes a change in magnetic flux so as to produce a current, the current enters the circuit with the outer circuit, so that the lamp turns on, because of a coil that can rotate through a magnetic field and produce magnetic flux. The rotating coil causes a change in magnetic flux so that it cuts the coil. This will produce a current. Like the Figure 1.

This respondent's answer has used the concept clearly, linking the problem with the generator working principle until the reasons for the problem are found. The mental model of respondents has guided specific and explicit goals. Respondents in explaining physics phenomena also use representations in the form of images, diagrams and analogies.

M22 final test answers:

"The reason why two alternative solutions to the problem were taken because accelerating the flow of water will cause the turbine will spin faster. The faster water flow and turbines spinning rapidly the better the electric generator work (based on principle), so that the light produced will be maximally bright and there will be no more dim lights. Because basically the lights that light up with the help of an electric generator will also die or get to the minimum point (0) but we cannot see it because it is visible because the resulting frequency is approximately 60 Hz. It means 60 per second waves. To produce a bright enough light by increasing the number of coils on the electric generator it is very supportive because the more the number of coils will produce a large magnetic induction so that the current will also increase."

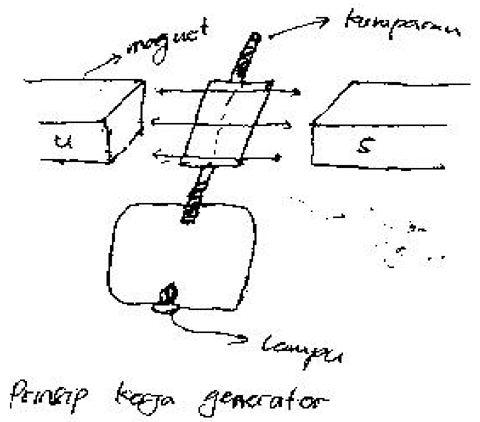

Figure 1. Working principle of generator (M15 student answer)

Respondents at this level are able to build a mental model by connecting the problem of lights that flash with the speed of water flow and turbines. Respondents are also able to connect the concept of waves to alternating current (AC) with the lights through the frequency concept; able to represent mental models macroscopically and microscopically; and using mathematical representations to further clarify the physical phenomena displayed.

The description above shows that the mental models of prospective physics teacher students on the concepts of electricity and magnetism are diverse. Each individual has their own way of building their mental model based on experience, analytic skills, and also the establishment of concepts they have. Students build their mental models depending on context, are dynamic and depend on student groups (the initial knowledge they have). The data are in line with research conducted by Corpuz and Rebello (2011) which revealed that mental models are essentially dynamic and context dependent and depend on the expert and novice groups (Chi, et al, 1981). This research data shows that students who have a level 1 mental model do not have an established concept and are not able to connect between reality and their concepts. This is the importance of the stage of brainstorming (Phase 3) carried out together in groups consisting of heterogeneous in terms of academic ability. At this stage also carried out efforts to train prospective physics teacher students in building, changing, or modifying mental models and using them in problem solving (mental modeling ability process).

Activities in this learning program directly make students care about doing meta-cognition, what and how mental models can help in understanding problems (Mark, 2012). The same thing is also stated by Lee, et al (2005) that alternative conceptions and mental models as part of cognitive psychology if combined in science learning, will be the approach that produces the best learning (Lee, et al, 2005). Likewise the tests used in evaluating utilized a form of rich problem tests. This form test allows students to use all their knowledge skills to analyze qualitatively before manipulating mathematical equations, connecting concepts in context, looking for alternatives, and evaluating the solutions (Al-Diban, & Ifenthaler, 2011; Heller & Heller, 2010).

The program have already trained students to produce mental models in the form of diagrams or other relevant forms of representation (Phase 3), reconstructing, manipulating, or adjusting mental models based on propositions or problem conditions (Phase 4). This learning program also trains students to reconstruct their approaches to problems and constantly monitors the process of explaining and constructing their mental models, checking and matching their mental models and answering using alternative approaches if problems are relatively new (Phase 5). From this whole process, it is expected that trained students solve problems based on H-MMA indicators/ criteria. This problem solving based learning strategy is consistent with the results of Wang (2007) research that applies problem-based lectures that have been able to increase student MMA on the molecular structure and Marks (2012) who applies problem-based learning and POE strategy interviews to improve students' mental modeling skills on dynamic electricity topics.

The increase in student MMA is both in the topic of electricity and magnetism, in line with research conducted by Wang (2007) which resulted that students with novice and intermediate categories are more easily intervened through learning than the expert group. Jusman (2010) in his research found that MMA respondents increased along with the increase of their academic level. This implicitly explains that the learning process influences the increase in the MMA category (Mansyur, 2010; Maloney, et al, 2008; Koponen, 2007).

The following are examples of thinking aloud and Interview about Event (IAE) of M22 respondents. Transcripts of thinking aloud M22:

"[Reading the problem of number 1 electricity] ... um ... the location of the farm location ... under SUTET (high voltage power line) [the student repeats but slowly while analyzing the problem]. Eee .. [scratching his head while looking blankly in the future like thinking about something]. [Returns writing] compass ... draws a compass [silence] (the results of the image are shown in Figure 2). (Again watching the problem) using a compass ... using a compass. eeee ... we have what this is ahhhhh ... We know that the compass ... (while looking around) is a tool ... (staring up) that can help find out the amount of current. Because of the increasing voltage, the ... (pause) the compass will be affected by the voltage because the compass is also affected by the voltage. So ... (while looking at the question closer) the electricity ... then ... the bigger the magnetic field ... the compass will deviate, deviate ... (write) "this compass before it is in the location of the SUTET. After the location of the SUTET, the compass will deviate either up or down.

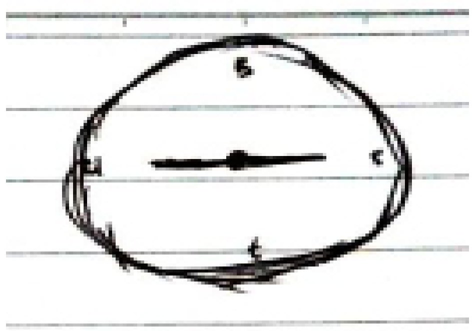

Figure 2. Figure of compass by M22

M22 writes (draws) the compass after being in the SUTET location (drawing) Figure 3.

"Suppose this south east is west of this north. Here is a deviation."

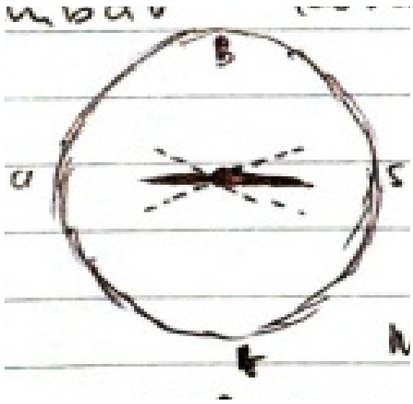

Figure 3. Picture of compass deviation by M22

"The images of these points are images of deviation from the compass needle (Figure 3). Deviations up or down we do not know depends on the source of the magnet."

The results of the interview with M22 also confirmed that M22 remained in its concrete thinking, namely compass. M22 does not think of the concept that "around a wire with a magnetic field". The following is the quote:

Q: After you read the problem at number one what do you think?

M22: It's good, sir, because it's affected by magnetic fields. Because the greater the magnetic field, the compass gets bigger and bigger [...].

Q: What do you think is a solution?

M22: I think that is a solution from me too sir...

Q: Or ... has there been any previous experience?

M22: If you don't have experience.

Q: [...] do you also think about what concepts can be applied to solve the solution?

M22: I do not master the concept of sir. Still shallow....

M22: Yes Sir. Make what I think is a compass. So, I described the compass first.

Thinking aloud results and M22 interviews in the context of number one magnetic material in forming a problem solving model that starts with analyzing the problem context qualitatively along with images, always monitoring the problem solving process by matching each answer with the problem, and self-checking the results of the work. But the model built at the beginning does not change when there is a new thought "the magnetic field is affected by the magnitude of the voltage" (perhaps considered wrong), M22 remains in the compass as a concrete matter.

CONCLUSION

Based on the data analysis and the discussion, it can be concluded that the learning program developed is able to improve MM and to increase the MMA of Physics teacher candidates, especially the concepts of electricity and magnetism. A significant phase in improving MM is the phase of brainstorming (Phase 3). At this phase students are guided to form MM through discussions with group members. A significant phase in improving MMA is the phase of guiding individual and group investigations based on problem solving (Phase 4) and the phase of evaluating problem solving results (Phase 5). In these two phases students are trained to use MM to solve problems and monitor every stage of the problem solving process.

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