Identifying pre-service physics teacher mental model on electric conceptions

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Abstract. This study aims to identify the MMoE of pre-service physics teacher who had followed the Basic Physics 2 subject, especially in electricity concept. Phenomenological method was used to describe the MMoE of 49 pre-service physics teachers. The results showed that the respondents’ MMoE at level 1 is 50.2%, at level 2 is 16.7%, at level 3 is 3.3% and inaccessible MMoE is 29.8%. This profile suggests that in analyzing the problems, pre-service physics teachers answer the questions based on intuition and daily experience without using the appropriate concept. Pre-service physics teachers are incapable of analyzing, accessing, constructing element of the knowledge gained during the lecture, and their answers were not coherently represented. Based on the analysis of data and research results, it seems that learning applied do not help pre-service physics teachers organizing knowledge in solving problems.

Keywords: electricity concept; mental model; pre-service physics teacher; problem solving test.

1. Introduction

Physics learning process in college focuses on equipping pre-service physics teachers in order to be able to solve problems based on scientific principles [1]. It leads many researchers looking for the causes of the low ability of pre-service physics teachers in solving problems and finding the methods to overcome them.

Every pre-service physics teacher each have the means to analyze the problems in accordance with the experience, knowledge and their ability to connect the knowledge and experience to form a pattern of problem solving in mind (mental models). Mental models is a key concept in understanding the concepts of science (including physics) [2, 3, 4, 5, 6]. Pre-service physics teachers solve problems not only based on experience that is seen, heard and done [6], but also based on more critical understanding of the interaction of causal and functional relationships of systemic problems [7, 8].

Based on researchers’ experiences on basic physics 2, pre-service physics teachers cannot solve the problem properly [9, 10]. Most pre-service physics teachers complete the test using their memory (memory-based-approach). Namely the situation analysis of the previous example, the process of solving the problem is by trying to "match" existing variables to these examples, referring to the
concept based on the variables, and the results were not evaluated [11]. Pre-service physics teachers are not capable of analyzing, accessing, constructing elements of the knowledge gained during the lectures and presents the answer coherently. It is very distressing, as the pre-service physics teachers. Improper conceptual construction leads to misconception that will pass on to the students later while working as a teacher.

MMoE is an internal representation of students in accessing the structure of their knowledge (content knowledge and daily experiences) used in solving the problems related to the concept of electricity. Based on previous studies: the mental model errors can cause errors in solving problems and tendency of misconception [12, 13, 14, 15]. However, mental models cannot observe directly, it can notice through the processes by problem solver in solving the problems [6, 16].

This research aims to identify the MMoE profile of pre-service physics teachers on the electricity concept. The benefit of this research is it can use as a consideration in developing lecturing programs that can improve MMoE and problems solving ability of pre-service physics teachers.

2. Methodology
The method used in this research is phenomenology. This method used to describe pre-service physics teachers’ MMoE profile at electricity concept. The sample consisted of 75.5% (37) females and 24.5% (12) males between the ages of 18-20 years old while taking basic physics 2 subject in the second semester. Most of them graduated from high school outside the city. Supporting lecturer has been teaching Basic Physics 2 Course for more than 10 years.

Instruments used is in the form of problem solving test modified from Heller & Heller [17] rich problem test and has been validated by five experts, three experts from the university in Bandung and two experts from the university in Palu. It consists of five contexts: electric charge, resistivity, a capacitor, a switch combination, and Kirchhoff’s rules.

Data collected by giving the test to 49 pre-service physics teachers who have just completed the electricity subject. The test was conducted one week after the student has completed the course. Since the mental model is an entity of internal representation, the researchers add instructions in the test: "Write clearly all things that come to your mind when solving the problems on the answer sheet! (Incloude sketches, drawings, graphs, or tables)". In order to obtain accurate information, the researchers also conducted random interviews to pre-service teachers shortly after they submitted their answers.

MMoE analyzed based on the problems solving results by referring to the categories implemented by Grosslight, Unger, Jay, and Smith [18]. The scores of problem solving (PS) is determined based on the problem solving rubric.

3. Results and discussion
The results of the MMoE level analysis and the mean score of PS shown in Table 1. Students in the category NA (not access) is a group of students who simply write the answers in the form of illustration without explanation or empty.

Table I. Percentage of the students at each MMoE level and PS score on each context

| Context | Mental Model on Electricity (MMoE) (%) | PS Score Mean |
|---------|-------------------------------------|---------------|
|         | NA   | level 1 | level 2 | level 3 |          |
| 1       | 24,5 | 61,2    | 10,2    | 4,1    | 3,1      |
| 2       | 38,8 | 57,1    | 4,1     | 0,0    | 2,4      |
| 3       | 26,5 | 49,0    | 24,5    | 0,0    | 2,7      |
| 4       | 22,4 | 49,0    | 26,5    | 2,0    | 3,2      |
| 5       | 36,7 | 34,7    | 18,4    | 10,2   | 2,7      |
| Mean    | 29,8 | 50,2    | 16,7    | 3,3    | 2,8      |
Based on Table I above, half of pre-service physics teachers are at MMoE level 1 (50.2%). Pre-service physics teachers at this level form mental models based on experience and knowledge that do not fit the context. They do not have the ability to access and interconnect concepts that has been learnt in the course. In fact, there are likely based on intuition, does not describe a physics learner. There are 16.7% pre-service teachers at MMoE level 2. At this level, they have formed a mental model based on the concept and specifically, lead to expected solution, but it is still rigid, it cannot be developed to test the accuracy of the solution. They do not change the mental model or match the solution with the mental model that has been built. Meanwhile, there are 3.3% pre-service teachers at MMoE level 3 who construct a mental model in analyzing the context based on the concept, through the representation of diagrams or pictures, display alternative solutions, and the mathematical equation in that context. There are several of them at thous level who didnot do self-checking, using other approaches in the problems solving process so that they do not change or develop the mental models built.

In context 1, pre-service teachers tend to think about the concrete form of photocopier and its working principle, they simply cannot find a solution that is expected. Only half of them start analyzing the context by thinking that positively and negatively charged object will attract each other.

In number 2 context, pre-service teachers tend to analyze the illustration of different metal sectional area, equating the symbol of \( \rho \) with density, only a few of them make predictions right but it is not applied in the further problems solving process.

In number 3 context, pre-service teachers tend to answer by considering power equation \( P = VI \) than write the variable and question, considering concrete model of the camera, the functions of capacitors. Few of them understand the function of the capacitor and to increase power from 144 watts to 180 watts light, the capacitors capacity should be enlarged, but they are not able to connect the power equation above by the equation \( C = Q/V \). So, they answer it just by logic without providing answers based on the above equation.

In number 4 context, most of pre-service teachers have already analyzed the problem by drawing the circuit but the positive-negative relationship of batteries and bulbs is not clear, without captions as if the illustration was drawn without consideration that indicates poor knowledge of the concept. Only a small proportion of pre-service teachers who describe parallel-series circuits correctly. However, only a few of them who explain the working principle of the circuit properly. They are familiar with the series and parallel circuits, but they are not able to produce a combination of the circuits expected in the problem context.

In number 5 context, most pre-service teachers consider the problem by redescribing the circuit as shown in the problem. They have difficulty in determining the concepts used to answer the problem by drawing pictures without any information at all. Only a few of them capable of thinking by describing the current flow in each loop, and then logical explain the problem.

Base on data, the higher pre-service teachers MMoE level (NC to level 3) the method used to solve the problem is better, the access to the memory of knowledge, analyzing problems and connecting related concepts are also more appropriate. One example of a great MMoE level (level 3) from context number 5: Through the image drawn by a pre-service teacher shows the results of the analysis: why the lights R2 in the circuit (a) is the brightest?

Pre-Service wrote the solution: Analyzing the current flow in each loop qualitatively. Then, deciding the answer based on the analysis. The answer given is the current flown in bulb R2 from two sources is in same direction. Thus, the current in R2 is two times bigger than R1 and R3. The analysis was supported by illustration. The Calculating by using mathematic equation to analyze it quantitatively \( \sum E = \sum iR \) then compare each current value determined by using the equation to decide the quality of bulb light.
The overview of the pre-service physics teachers MMOE profile data on the concept of electricity is very diverse. Every individual has their own way to build mental models based on experience, reliable concepts and analysis capabilities, the speed and accuracy of selecting the proper concept. It is in line with Corpuz and Rebello who stated that mental model of pre-service teachers is their method of organizing experiences to minimize mental labour in explaining the surrounding world [12, 16]. Likewise, according to Vosniadou, Skopeliti, and Ikospentaki (2004), to understand how the system works, people need to construct a mental model of the system in mind, namely to build a network of related concepts and understand the functional relationships of aspects and different levels of the system is based on the knowledge and daily experience [19]. Data shows that most of the pre-service physics teachers are at MMOE level 1. A mental model is fragile. Pre-service physics teachers do not have an established concept and was not able to connect between the concept and the context of problem or vice versa.

Based on the interview result with some students when they were asked "Are there any difficulties when taking the test?" Simultaneously, they answered "We are confused, Sir. What is the question? What are the variables unclear!". It is obvious that the pre-service physics teachers are not ready for problem solving test which is different from question practiced (exercise) [1]. They are familiar with the memory-based approach problems.

The explanation above shows that MMOE built has great influence on the pattern of problem solving process applied by pre-service physics teachers. How do they use a concept in depth or everyday reality to analyze and solve problems? It is an evaluation of the learning approach that used and it is necessary to determine an alternative to appropriate learning approach [20]. It should be a learning approach that not only makes pre-service physics teacher learnt, but also paid attention to how they interact and respond to the environment and learning materials [21].

4. Conclusion
In conclusion, the pre-service physics teachers’ MMOE profile are very diverse and they tend to still rely on daily experiences without the support of an established concept. This profile can be used as an alternative for evaluating learning approach which has been used and a consideration in selecting the appropriate approach in teaching electrical concept further. Related to the results of the study and discussion, some of the following recommendations can be withdrawn: 1) Identifying the MMOE profile of pre-service physics teachers can be used as the evaluation in which it is necessary to design an alternative yet appropriate learning approach, and 2) Further research can be conducted in order to find an alternative approach to increase the level of pre-service physics teachers’ mental model related to electricity concepts.

References
[1] Korsunsky, B., 2004. Ready, SET, Go! A research-Based Approach to Problem Solving. Jurnal The Physics Teacher. 42, 493-497.
[2] Marks, J.B., 2012. Understanding Key Concepts of Electric Circuits. Student use of Mental Models. Thesis Submited for a Ph.D degree. Departement of Education, University of York.
[3] Coll, R.K., & Lajium, D., 2011. Modeling and the future of science learning. In M. S. Khine & I. M. Saleh (Eds.), Models and modeling: Cognitive tools for scientific enquiry (vol.6, pp. 3-21). Dordrecht, The Netherlands: Springer.

[4] Ramadas, J., 2009. Visual and Spatial Modes in Science Learning. International Journal of Science Education, pp. 1-17, February 2009. Taylor & Francis.

[5] Greca, I. M., and Moreira, M. A., 2000. Mental models, conceptual models, and modelling. International Journal of Science Education. Vol 22. No 1. P 1-11.

[6] Gilbert, J. K. (ed.), 2005. Mental models: theoretical issues for visualizations in science education. Journal Visualization in Science Education. 43-60.

[7] Chan, M.S., and Black, J.B., 2006. “Learning Newtonian Mechanics with an Animation Game: the Role of Presentation Format on Mental Model Acquisition”. Paper presented at the Annual Meeting of the American Educational Research Association (AERA), San Francisco, California.

[8] Coll, R.K., 2008. Chemistry Learners’ Preferred Mental Models for Chemical Bonding. Journal of Turkish Science Education. 5, (1), 22-47.

[9] Supriyatman, Suhandi, A., Rusdiana, D., Samsudin, A., and Wibowo, F. C., 2018. Problem solving laboratory-based course development to improve mental model and mental-modeling ability. Proceeding ICE-201, Atlantis Press: Advances in Social Science, Education and Humanities Research, volume 174.

[10] Samsudin, A., Fratiwi, N., Amin, N., Wiendartun, Supriyatman, Wibowo, F., Faizin, M., and Costu, B., 2018. Improving students’ conceptions on fluid dynamics through peer teaching model with PDEODE (PTM-PDEODE). Journal of Physics: Conf. Series 1013 (2018) 012040.

[11] Walsh, L. N., Howard, R. G., and Bowe, B., 2007. Phenomenographic Study of Students’ problems solving approaches in physics. Journal Physics Review Special Topics PER. 3, 020108.

[12] Corpuz, E. D., and Rebello, N. S., 2011. Investigating students’ mental models and knowledge construction of microscopic friction. II. implications for curriculum design and development. Physics Review Special Topics PER. 7, (2), 020103-1 – 020103-8.

[13] Wang, C.Y., 2007. The Role of Mental-Modeling Ability, Content Knowledge, and Mental Models in General Chemistry Students’ Understanding about Molecular Polarity. Ph.D Dissertation Columbia: University of Missouri.

[14] Mansyur, J., 2010. Kajian fenomenografi aspek-aspek model mental Subyek lintas level akademik dalam Problem solving konsep dasar mekanika. Desertasi Doktor pada Jurusan Pendidikan IPA SPs UPI Bandung: tidak diterbitkan.

[15] Yayla, R. G., and Eyceyurt, G., 2011. Mental Models of Pre-Service Science Teachers about Basic Concepts in Chemistry. Journal: WAJES. Dokuz Eylul University Institute, Izmir, Turkey. ISSN 1308-8971.

[16] Corpuz, E.D., and Rebello, N. S., 2011. Investigating students’ mental models and knowledge construction of microscopic friction. I. implications for curriculum design and development. Physics Review Special Topics PER. 7, (2), 020102-1 - 020102-9

[17] Heller, K., and Heller, P., 1999. Problem-Solving Labs. Introductory Physics I Mechanics. Cooperative Group Problem-solving in Physics. University of Minnesota.

[18] Jansoon, N., Coll, R.K., and Somsook, E., 2009. Understanding mental models of dilution in Thai students. International Journal of Environmental & Science Education. 4, (2), 147–168.

[19] Vosniadou, S., Skopeliti, I., & Ikospentaki, K., 2004. Modes of knowing and ways of reasoning in elementary astronomy. Cognitive Development, 19, pp.203-222.

[20] Brock, M.E., et al., 2008. “Mental Models: An Alternative Evaluation of a Sensemaking Approach to Ethics Instruction”. Journal of Science Engineering Ethics. 14, 449-472. Springer.
[21] Redisk, Edwar F., 1994. Implications of cognitive studies for teaching physics. *American Journal of Physics*. Vol 62 No 9 p. 796-803.