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THE EFFECTIVENESS OF LEARNING TO REPRESENT PHYSICS CONCEPT APPROACH: PREPARING PRE-SERVICE PHYSICS TEACHERS TO BE GOOD TEACHERS

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ABSTRACT

Determining what to teach to pre-service teachers, how to teach it, and what skills they should have, should refer to empirical facts. The research aimed to measure the effectiveness of the design of learning to represent physics concepts in improving the ability of pre-service physics teachers to make translation among representational modes and make multiple representations of physics concepts. This instructional approach design is embedded in the physics subjects with selected topics. Research outcomes showed that the approach had a high significance in improving the ability of making multiple representations of concept and translating among modes of representation for the domains of waves and optics and electromagnetism.

The pre-service physics teacher's abilities in making multiple representations of physics concepts and translating among representational modes improved with average normalized gains in the criteria of low to moderate. Their ability in making multiple representations of physics concepts could be explained for 37% by the ability in making translation among types of representational modes through linear relationship with the formulation of $X = 6.77 + 0.33Y$. Based on the interview with the pre-service teachers, another factor was found to influence the ability of making multiple representations, namely their ability of understanding physics concepts and the domain of the concepts to be represented.

KEYWORDS: Learning to Represent Physics Concepts, Pre-Service Teacher, Effectiveness of Learning Approach, Multiple Representations, Translation among Representational Modes

INTRODUCTION

It is the right of every primary and secondary school student to have quality teachers, regardless of where they are and what their backgrounds are. Each state stipulates standards of quality teachers based on its respective national education objectives. Indonesian National Standard Education pertaining to teacher standard competences Indonesian Minister of National Education Decrees [1] have been developed holistically from the main four components, namely: Pedagogic, personal, social, and professional competences. The pedagogic competences for physics teachers are, among others, knowing the characteristics of and identifying student's learning difficulties in physics.

Professional competences are, among others, developing, selecting, and processing physics instructional materials creatively in accordance with student's developmental level. Because teachers are prepared by institutions such as teacher training institutes, the question is then "How can teacher training institutes prepare pre-service physics teachers to have the ability of developing instructional materials creatively in accordance with student's characteristics and learning difficulties?" Determining what to be taught to the pre-service teachers, how to teach it, and what skills required by them should refer to empirical facts. One of the significances of teacher education is that teachers have to help students fulfill the academic standards, namely graduate competence standard according to the level and subject.

The question has been partially addressed by research results on the use of multiple representations in science instruction (See: B. Hinrichs [2], N. Finkelstein et al [3], Patrich B Kohl et al [4], Vaughan Prain et al [5], D. Rosengrant et al.[6], C deLeone & E. Gire, [7], D Rosengrant et al.[8], D. Rosengrant et al [9]; P. Kohl & N Finkelstein [10]; Patrich B Kohl et al.[11]; P Kohl & N Finkelstein [10]; M. Dancy & R. Beichner,[12]; D. Meltzer, [13]. The previous research results showed that the use of concept multiple representations in natural science instruction can help students understand in-depth science concepts, solve science problems, and ask some questions. The results suggested the significance of pre-service physics teachers to have the ability of developing instructional materials using multiple representations.

Present day's situation demonstrates that the curriculum of physics education department in various teacher training institutes has not included a subject specifically made to teach pre-service teachers the ability of making multiple representations of physics concepts. Physics subjects in physics education department in teacher training institutes have merely focused on how pre-service teachers understand instructional materials. They have not been encouraged to think of how to re-represent the concepts in physics instruction in secondary schools in the future. Facts in the field show that the majority of secondary school teachers only use the representational modes of text and mathematical equations in explaining physics concepts. The physics teachers have not prepared teaching materials by considering their student's characteristics and diverse difficulties in learning physics. Such a condition has an impact on secondary school student's perceptions of physics subject in Indonesia. Observation results proved that the subject the majority of students think to be the most difficult and most disliked was physics. The same finding has also been put forward by previous researchers Meltzer [14]; Meltzer [15]; Flores et al.{16; Beichner,{17]; and Funda Ornec[18] who found that each student had dissimilar difficulties in understanding physics concepts.

The condition is very disadvantageous for Indonesia in its current attempt to build its human resources, who are expected to master science and technology in the future. Teacher training institutes as institutions educating and preparing pre-service teachers should address the gap between the demands of national competence standards for teachers and the low teacher competence in making multiple representations of concept in physics instruction in schools. Considering the fact that to propose an inclusion of a new subject will require curriculum changes, what can be done in the meantime is designing an instructional approach aimed to improve the ability of representing concepts for pre-service teachers. The issue under research is how to improve the ability of pre-service physics teachers in making multiple representations of physics concepts.

The issue is elaborated into the following research questions: 1) How effective is the learning to represent physics concept approach embedded in physics courses with selected topics in improving pre-service teacher's abilities of making multiple representations of and translating physics concepts?; 2) How do pre-service teacher's abilities in making multiple representations of concept and translating among representational modes improve in the subject matters of electromagnetism before and after the approach is embedded in the course?; 3) What difficulties they experience in making multiple representations of and translating among representational modes of physics concepts?; and 4) How does the ability of translating among representational modes correlate to the ability of making multiple representations of concepts?

Multiple representations mean representing the same concept using several representational modes. Representing physics concepts using multiple representations will provide students from various backgrounds with opportunities to understand physics according to the representational mode they most easily understand. In other words, physics concepts described in multiple representations have the potentials to solve the diverse learning difficulties students experience in physics. In order to be able to make multiple representations, a teacher has to be skilled in translating among representational modes. Translation among representational modes is changing the representation of a concept using certain mode into another representational mode Ainsworth [19]. The process of translating from the source representational mode into target representational mode in general needs a medium, which is termed a mode of transitional representation Bosse, et al [20].

The significance of this research is the development of learning to represent physics concept instructional approach to improve the competence of pre-service physics teachers in making multiple representations of physics concepts. The approach will enrich the various instructional approaches applicable in teacher training institutes.

METHODS

The approach of learning to represent physics concepts was embedded in physics course with selected topics with 2 x 50 minute-lesson per week. A total of 20 students were involved. The small sample was selected to allow for intensive supervision of each student's multiple representations of concepts. The first week (2 x 50 minutes) discussed topics under the subject matter of electromagnetism, whose content was in line with the curriculum of secondary school physics. In the second week (2 x 50 minutes), types of representational modes used in textbooks on electromagnetism and waves were introduced. Each student was then assigned to represent a concept in the subject matter of waves and another in the subject matter of electromagnetism using the representational modes they mastered the most. Several students were asked to present their tasks before the class.

Other students commented on whether the concept represented using certain type of representational mode could be easily understood and whether the information of the concept had been completely provided. At this stage, the pre-service teachers were expected to gain knowledge on how each type of representational mode had limitations and that a physics concept could not be completely explained using one type of representational mode. Pre-test on the ability of translating among representational modes was given in the third week (2 x 50 minutes), continued by students practicing translation among types of representational modes. The translation was done using transitional representation.

The students practiced on determining which transitional mode was the most appropriate to translate each source mode into target mode. The fourth week (6 x 50 minutes) was begun with a post-test on the ability of translating among types of representational modes. It was followed by discussion on the importance of teachers to have the ability of making multiple representations of concepts to instruct students with various characteristics and difficulties in learning physics. Examples of the use of multiple representations in physics textbooks were given.

The students practice to make multiple representations of a physics concept. They were each assigned to make multiple representations of a concept included under the subject matter of waves and another concept under the subject matter of electromagnetism. Several students presented their assignments before the class, while other students and the lecturer provided comments and suggestions. The comments provided referred to whether all representational modes used could explain the same concept; whether there were other representational modes that could be added to the multiple representations; whether each representational mode in the multiple representations had completed each other; and whether the information on physics concept explained could be better understood. The comments and suggestions gained were then made references by each student to revise the assignment. This stage was completed with a post-test on the ability of making multiple representations of concept.

Research instruments took the form of questions with short answers to measure the abilities of multiple representations of concept and translation among representational modes and face-to-face semi-structured interview to find student's difficulties. The data obtained were processed statistically by calculating the average normalized gains and were interpreted using Hake's criteria [21]. To find the effectiveness of learning to represent physics concept approach, effect size was analyzed, using the formula proposed by Robert Coe [22], and was then interpreted using Cohen criteria [23]. To find the correlation of student's ability in making multiple representations and the ability of translating among types of representational modes, regression analysis and product moment correlation were done in order to gain the correlation coefficient value and coefficient of determination Sudjana, [24], while interview data were described.

RESULTS

The effectiveness of treatment on the improvement of pre-service teacher's abilities in making multiple representations and translating among types of representational modes are shown in tables 1 and 2.

Table 1: The Effect Size of Multiple Representations of Concept

Topic	Pretest Mean	Posttest Mean	Pretest STDEV	Posttest STDEV	Effect Size
Waves and Optics	44.08	77.41	21.20	20.37	1.6 (high)
Electromagnetism	33.33	51.1	9.7	10.26	1.7 (high)

Table 2: The Effect Size of Translating among Representational Modes

Topic	Pretest Mean	Posttest Mean	Pretest STDEV	Posttest STDEV	Effect Size (d)
Waves and Optics	40.51	55.38	16.24	17.89	0.87 (high)
Electromagnetism	37.85	49.94	15.91	13.06	0.85 (high)

The improvement of multiple representation ability

The average normalized gain for the abilities of making multiple representations of concept and translating among types of representational modes on the domains of electromagnetism and waves and optics are given in table 3 and 4.

Table 3: The Average Normalized Gain for Multiple Representations of Concept

Topic	% <Pretest>	% <Posttest>	Normalized % <Gain>
Waves and Optics	48.9	69.8	41 (medium)
Electromagnetism	40	50.6	18 (low)

Table 4: The Average Normalized Gain for Translation among Representational Modes

Topic	% <Pretest>	% <Posttest>	N <Gain>
Waves and Optics	40.5	55.4	25 (low)
Electromagnetism	41.5	54.1	21 (low)

The ability to translate from the source representational mode into the target mode for the subject matters of waves and electromagnetism is described in tables 5 and 6.

Table 5: Translation from the Source Representational Mode into the Target Rep. Mode on Electromagnetism

Source Rep. Mode	Target Rep. Mode	% <Pretest>	% <Posttest>	N % <Gain>
Text	Pictorial diagram, graph, table, mathematical equation	39	55	26 (low)
Picture	Text, pictorial diagram	56	69	30 (medium)
Mathematical equation	Text, pictorial diagram, graph, picture	21	35	18 (low)
Pictorial	Text, mathematical equation, table	31	44	19 (low)
FBD	Text, mathematical equation, table	31	46	22(low)
Graph	Text, mathematical equation	19	38	23 (low)

Table 6: Translation from Source Representational Mode into Target Representational Mode on the Subject of Waves

Source Rep. Mode	Target Rep. Mode	% <Pretest>	% <Posttest>	N % <Gain>
Text	Pictorial diagram, graph, table, mathematical equation	47	66,5	31 (medium)
Table	Text, diagram pictorial	22	38,4	21 (low)
Graph	Text, diagram pictorial, graph, picture	44	54,1	18 (low)
Picture	Text, mathematical equation, table	19	40,1	26 (low)
Pictorial	Text, mathematical equation	8	35	31(Medium)

DISCUSSIONS

The research data (tables 1 and 2) proved that learning to represent physics concept approach embedded in the physics course with selected topics was empirically effective in improving student's abilities in making multiple representations of concept and translating among types of representational modes. The effect size coefficient for the two abilities was in the high criterion ($d > 0.8$) based on Cohen's interpretation. This fact showed that the activity designed in learning to represent physics concept approach could achieve the set instructional objectives.

The approach was designed with the following orders: Types of representational modes of concept, translation among representational modes, and multiple representations. Translating among representational modes can only be done if the students have already been familiar with types of representational modes. Based on the source and target representational modes, students should be able to determine the most appropriate mode of transitional representation. Students can make multiple representations of concept on the grounds that they have been able to translate among representational modes. Control over the correctness of the multiple representations of concept made is determined by student's understanding of physics concepts. They have to be able to evaluate whether the multiple representations wholly explained the same or different concept. Peer and expert reviews followed by suggestions provided during student's presentation of their assignment are very beneficial in improving their ability in evaluating the multiple representations of concept they made.

The ability to make multiple representations of physics concepts, in addition to depend on the domain, is dependent upon student's understanding of physics concepts. On the questionnaire and during interview on making multiple representations of concept conducted after students learned, practiced, and did their assignments related to making multiple representations of physics concept, the majority of students stated that in-depth understanding of the physics concepts to be represented highly determined their ability in making multiple representations and that each representational mode presented them with particular difficulties. When making representations of Coulomb law using representational modes of table, for instance, they experienced difficulties in making tables in such a way that readers could clearly see the direct correlation among variables included in the table and in determining which variables to display on the tables. Representing Coulomb law with table mode had limitations in that the mode could only explain that the amount of attractive or repulsive forces between two electric charges is inversely proportional to the square of the distance between the two charges and directly proportional to the amount of each electric charge, but unable to explain the direction of the forces.

Hence, students should complete Coulomb law’s representation with another mode, such as pictorial diagram. Using pictorial diagram, students could show the influence of the distance and amount of the two charges on the working force of each charge. The trouble students were still posed with was to picture the amount and direction of forces correctly. Picturing two-newton and eight-newton forces should be done by comparing the correct vector length, but the majority of the students did not pay attention to the scale.

Meanwhile, research results as presented in tables 3 and 4 revealed that learning to represent physics concept approach was effective in improving the pre-service teacher’s ability in translating among representational modes. Research results showed that this ability was also influenced by the domain. The average normalized gain for the ability of translating among representational modes for the domains of waves and optics and electromagnetism were both included under the low criterion. It can be observed from the characteristics of the two domains, where the concepts of electromagnetism subject matter were more abstract than those of waves and optics.

Results of questionnaire and interview revealed in relation to translation among types of representational modes showed that almost all pre-service teachers (87%) stated that sometimes they experienced difficulties depending on whether they understood the concept contained in the source representational mode given. If they did not understand the concept, they would not have ideas to translate from the source representational mode into the target mode. Questionnaire results further revealed that another factor influencing the ability of translating among representational modes was due to difficulty in selecting modes of transitional representation, as put forward by 76% of the pre-service teachers. If the mode of transitional representation was inappropriate, the target mode will be incorrect.

The source representational modes for electromagnetism in this research were text (narration), picture, mathematical equation, pictorial diagram, free body diagram, and graph. The ability to translate from the source representational mode into the target representational mode is demonstrated in table 5. The research found that for the domain of electromagnetism, translation from mathematical equation representational mode into another mode was the most difficult. Meanwhile, translation from mathematical equation into graph required a medium, namely table mode. If the physics equation is simple, for instance only consisting of two parameters, a table explaining the correlation between the two parameters can be immediately made.

However, when the equation contains several parameters, students should at first determine which parameters are assumed to be constant and which ones are varied. Therefore, several tables should be made, and as a consequence, several graphs will be produced representing the equation. It was in this stage that most of the student teachers under research experienced difficulty, namely determining dependent and independent variables from a quite complex physics equation.

Translation from mathematical equation mode into picture requires that the physics equation be analyzed first, namely the correlation among the parameters. What follow is determining what to be described from the physics concept or law stated in the mathematical equation. In the case of Coulomb law, for example, students have to consider how to explain that repulsive or attractive forces between two electric charges is inversely proportional to the square of the distance between the two charges and directly proportional to the amount of each charge. This picture representational mode should be made in such a way that even though the audiences cannot see the physics equation, by seeing the picture, they can understand the correlation between one parameter and the other. The process needs to engage student's cognition, namely understanding on the physics concept to be represented. If the concept is difficult to understand; consequently, it will be difficult to determine what to be pictured or illustrated from the concept.

The ability to translate among representational modes on the domain of waves and optic, namely from the source modes of text (narration), table, graph, picture, and pictorial diagram into the target modes is shown in table 6. The lowest translation ability on the domain of waves and optics was on translating from the representational mode of graph into target mode. Translation from graph into mathematical equation needs the skill of reading graph, namely searching for information on what parameters stated in the graph. Based on the curve shape, students can determine the correlation among parameters, whether directly proportional, inversely proportional, etc. Based on the relationship, students can determine the equation connecting those parameters. Difficulties rose in the research, as pre-service teachers had still not been able to read graphs and determine the relationship among parameters listed in the graph based on the curve shape pictured. That was what caused the gain of the ability to translate from the representational mode of graph into other modes the lowest.

The correlation of the ability to make multiple representations and translate among types of representational modes is stated by the regression equation $X = 6.77 + 0.33Y$, with coefficient of determination (r^2) = 0.37. It means that 37% of the student's ability in making multiple representation of physics concept could be explained by their ability in translating among representational modes. Thus, it was indicated that the pre-service teacher's ability in making multiple representations of physics concepts, in addition to be influenced by their ability in translation among types of representational modes, was influenced by other factors. Results of analysis on interview and observation data during classroom instruction in making multiple representations demonstrated that their ability was also influenced by their understanding of physics concepts and the domain of the concepts to be represented.

CONCLUSIONS

Learning to represent physics concept approach embedded in physics courses with selected topics was effective in improving pre-service teacher's abilities in making multiple representations of concept and translating among representational modes. The abilities improved with average normalized gains that were in the criteria of low to medium. 37% of the student's ability in making multiple representations of physics concepts could be explained by their ability in making translation among types of representational modes through a linear correlation, with an equation of $X = 6.77 + 0.33Y$. Based on these findings, it was indicated that the pre-service teacher's ability in making multiple representations of physics concepts, in addition to be influenced by their ability in translation among types of representational modes, was influenced by other factors, namely: Their ability in understanding physics concept and the domain of the concepts to be represented, and the skills of making each type of representational modes.

The implication of this research on the instruction of preparation program for pre-service physics teacher is that the courses on subject matters need to provide additional abilities, namely the ability to re-represent concepts using multiple representations. Each topic in the course included in secondary school physics curriculum should be taught using multiple representations, thus allowing students to learn to make multiple representations. By doing so, it is expected that pre-service physics teachers will not only be able to understand physics concepts for themselves, but also be skilled in representing the concepts to the secondary school students to help the students easily understand them.

REFERENCES

1. Kemendiknas, Peraturan mentri pendidikan nasional, stnadar nasional pendidikan Indonesia 2006.
2. Hinrichs, B. In edited by J. Marx, P. Heron, and S. Franklin, *Physics Education Research Conference Proceedings*, Sacramento, CA, 117-120, 2004.
3. Finkelstein, N. et.al. *Phys. Rev. ST Phys. Educ. Res. 1, 010103, (2005).*
4. Kohl, P. B. et al., *Physical review special topics. Physics Education research*, 3, 2007.
5. Prain. V, et al.. *International journal of Science Education*, Vol.31 No.6, 2009
6. Rosengrant, D., Van Heuvelen, A. and Etkina, E. In edited by J. Marx, P. Heron, and S. Franklin, *Physics Education Research Conference Proceedings*, Sacramento, CA, 2004, 177-180.
7. DeLeone, C. and Gire, E. edited by P. Heron, L. McCullough and J. Marx, *Physics Education Research Conference Proceedings*, Salt Lake City, UT, 45-48. 2005.
8. Rosengrant, D., Etkina, E. and Van Heuvelen, A. *National Association for Research in Science Teaching* Proceedings, San Francisco, CA. 2006.
9. Rosengrant, D., Van Heuvelen, A. and Etkina, E. edited by P. Heron, L. McCullough and J. Marx, *Physics Education Research Conference Proceedings*, Salt Lake City, UT, 2005, 49-52.
10. Kohl, P.B. and Finkelstein, N. edited by P. Heron, L. McCullough and J. Marx, *Physics Education Research Conference Proceedings*, Salt Lake City, UT, 2005, 93-96
11. Kohl, P.B. et al. Physical review special topics, *Physics educational research*, 4, 2008.
12. Dancy, M. and Beichner, R. *Phys. Rev. ST Phys. Educ. Res. 2, 010104.2006.*
13. Meltzer, D., *Am. J. Phys*., 73, 463-478. 2005.
14. Meltzer, D.E. The relationship between mathematics preparation and conceptual learning gains in physics: A possible “hidden variable” in diagnostic pretest scores. *Am. J. Phys*., 70, 2002.
15. Nguyen, N. and Meltzer, D.E. Initial understanding of vector concepts among students in introductory physics courses. *Am. J. Phys*., 2003. **71.**

16. Flores, S., S.E. Kanim, and C.H. Kautz, Student use of vectors in introductory mechanics. *Am. J. Phys*., 2004. **72**
17. Beichner, R.J Testing student interpretation of kinematics graphs. *American. Journal of Physics.*, ***62***.1994.
18. Ornek, F., Robinson, W.R., & Haugan, M, P. What makes physics difficult?, *Inernational journal of environmental and science Education*,3 (1). 2008.
19. Ainsworth. "The functions of multiple representations," *Computers & Education*, vol. 33, pp. 131-152, 1999.
20. Bosse, M.J., Gyamfi, K.A., & Cheetham, M Translations Among Mathematical Representations: Teacher Beliefs and Practices, Department of Mathematics, Science, and Instruction Technology Education, College of Education, East Carolina University, Greenville, NC 28590. 2011.
21. Hake, R. RRelationship of Individual student Normalized gains in Mechanics with gender, High school Physics, and pretest scores on mathematics and spatial visualization. Departmen of Physics, Indiana university, submitted to the *Physics education research conference*; Boise idaho. 2002. Tersedia di http://www.arxiv.org.
22. Coe Robert. What is an Effect Size ?. A Guide for User. Draft version. Unger. J. & Fleischman. S. *Is Process Writing the "Write Stuff" – Research Matters.* Printed in Educational Leadership, issue: October 2004, pages 90-91.
23. Cohen, J Statistical power analysis for the behavioral sciences, NY Academic press. 1969. In Coe Robert (2000) What is an effect size? Aguide for user, draft version.
24. Sudjana. Metode Statistika. Tarsito Bandung 1996.