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PRACTICALITY AND EFFECTIVENESS OF THE IBMR TEACHING MODEL TO IMPROVE PHYSICS PROBLEM SOLVING SKILLS

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Abstract. *The design of a teaching model must qualify to be applicable or practical and effective, therefore the research aimed to analyze the practicality and effectiveness of the IBMR (Investigation-Based Multiple Representation) teaching model in improving physics problems solving skills of bachelor programs' students. The research was conducted by applying the one-group pre-test and post-test pre-experimental design to 186 students of study program of physics education, mathematics education, and mechanical engineering. The practicality of the model is assessed using an observation sheet and the effectiveness is determined based on pre-test and post-test physics problem solving skills. The collected data were analyzed using the calculation of average scores of the feasibility of each phase of the IBMR, t-test, and n-gain. The results show that each phase of the IBMR teaching model can be implemented by a lecturer with good and reliable categories, and relevant student activities, so that the IBMR teaching model is practicality qualified. It is also effective shown by: there are increasing score of physics problem solving skills at a = 5%, average n-gain with moderate categorized and not different or consistent for each pair of groups, and good-categorized students' responses on each component of teaching.*

Keywords: *IBMR teaching model, model practicality, model effectiveness, physics problem solving skills, bachelor programs' students.*

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Introduction

An ability to solve problems presents as an important learning achievement in higher education in Indonesia. This is in accordance with one of the learning achievements required in the Presidential Regulation of the Republic of Indonesia No. 8 of 2012 regarding Level 6 Indonesian National Qualifications Framework (INQF). For that reason, physics learning in higher education should facilitate students to be able to solve physics problems.

Such statement is in line with arguments of Taasoobshirazi & Farley (2013) emphasizing that one of the main physics learning objectives in higher education is to improve students' ability in solving physics problems. Similarly, Walsh, Howard, & Bowe (2007) point out that the physics learning objective is to be able to solve problems by applying knowledge and understanding in everyday situations. Students should learn to solve problems because they are needed in real life (Phumeechanya & Wannapiroon, 2014; Bellanca & Brandt, 2010). Many researches have resulted in outcomes which support the importance of curriculum revision to include integrated learning environment that supports problem solving. Problem solving in physics learning, therefore, has been a tradition to give experience required in job after students graduate (Heller & Heller, 2010).

Students are said to succeed in physics learning if they are able to apply the knowledge obtained from the learning to solve physics problems. Such fact is in line with one of learning outcomes according to the INQF (Jatmiko, Widodo, Martini, Budiyanto, Wicaksono, & Pandiangan, 2016) and one of the 21st century learning achievements, problem solving (Bellanca & Brandt, 2010). However, the results of previous research conducted to lectures on basic physics in University of PGRI Semarang Indonesia indicate that students had low physics problem solving skills (Siswanto & Saefan, 2014). The results detail that 1) 77.27% of students found difficulties in physics problem solving due to their lack of understanding of problems given by their lecturer, while 22.73% of students did not understand the concepts, and 2) 23.81% of students solved problems by making lists of equations, 47.62% by identifying and making lists of the unknown and known quantities, 28,57% by looking up the existing examples on the book, and 0% by referring to experiments performed in previous lectures. The results of interviews with students

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demonstrated the lack of understanding the strategies used by students to solve problems. Students had no understanding of steps they did and no specific strategies in physics problem solving. Such results strengthen the results of the previous research reporting that physics learning in higher education has not yet been able to help students gain knowledge and physics problem solving skills (Taasoobshirazi & Farley, 2013; Henderson, 2005; Mc Dermott, 2001). For that reason, in physics learning in higher education, a lecturer should equip students in such a way that they are able to solve physics problems.

Learning which can improve problem solving skills includes: 1) Modeling Instruction (Hestenes, 1987; Wells, Hestenes, & Swackhamer, 1995; Halloun, 2007; Malone, 2007; Jackson, Dukerich, & Hestenes, 2008; Brewe, 2008; Wright, 2012) and (2) Problem-Based Learning (Skinner, Braunack-Mayer, & Winning, 2015; Ageorges, Bacilia, Poutot, & Blandin, 2014; Temel, 2014; Klegeris, 2013; and Arends, 2012). The former refers to a learning which accommodates physical modeling; which, according to Etkina, Warren, & Gentile (2006), can be used to describe and explain physics phenomena, while the latter is a learning which makes use of authentic and meaningful problems discovered by students as a starting point to acquire new knowledge (Stalker, Cullen, & Kloesel, 2014; Batdi, 2014; Temel, 2014). Therefore, both Modeling Instruction and Problem-Based Learning are often adapted in physics learning to improve students' physics problem solving skills. The implementation of Modeling Instruction and Problem-Based Learning, however, has some drawbacks. Student models are generally inadequate, they are generally difficult in transforming problems into models, and in making representations (Brewe, 2008; Niss, 2012; Deni, Langlang, & Sunyoto, 2013; and Sujarwanto, Hidayat, & Wartono, 2014). Meanwhile, implementing Problem-Based Learning will be effective if students have mastered basic concepts (Sockalingam & Schmidt, 2011). It happens since when students have not mastered basic concepts, they will find difficulties in understanding problems. Failure in understanding problems will in turn result in failure in solving problems.

The IBMR teaching model is specifically designed to improve problem solving skills through multiple representation applications from investigation results. The model has phases: orientation on the phenomena and the use of multiple representations, investigations, multiple representations, applications, and evaluations (Siswanto, Susantini, & Jatmiko, 2016). It is supported by constructivism learning theory and the results of a research conducted by Kohl & Finkelstein (2007) stating that problem solving is associated with representational knowledge, topics, and experience. De Cock (2012) adds the importance of abilities to interpret or construct representation, as well as abilities to translate and to switch from one representation to another; and Maries (2013) points out that multiple representations play a role in physics problem solving.

Multiple representations have three main functions, namely: (1) as complementary, multiple representations are used to provide complementary information or to help complete cognitive processes; (2) as constraining, multiple representation can be used to limit the possibility of interpreting errors in using other representations; and (3) as deeper understanding, multiple representations are used to help promote construction of deeper understanding (Ainsworth, 1999). The format of multiple representations is categorized into verbal, pictorial/ diagram, math, and graphical (Waldrip, Prain, & Carolan, 2010). Verbal representation functions to provide definition for a concept; pictorial representation/ diagrams help to visualize abstract concepts; math representation to solve quantitative problems based on qualitative representations; and graphical representation to present long explanation of a concept.

The present research demonstrates physics teaching using the IBMR teaching model to improve physics problem solving skills. The indicators of physics problem solving skills adapted from Young & Freedman (2012) and Selcuke, Caliskan, & Erol (2008) involve: problem identification, problem solving planning, implementation based on the planning, and evaluation.

Problem of Reported Research

The research problem was how to analyze the practicality (applicable in teaching) and effectiveness of the IBMR teaching model towards students' physics problem solving skills in basic physics teaching. The IBMR teaching model is said to be practical if each phase is performed by a lecturer in good and reliable categories, and students' activities are categorized relevant. Meanwhile, the IBMR teaching model is considered effective if there is an improvement of students' physics problem solving skills (statistically) at a = 5%, the average of normalized gain score (average of n-gain) is categorized as moderate, the average of n-gain is not different (consistent) for each pair of groups, and students' responses towards the teaching model for each component are categorized good.

The present research seeks to improve physics problem solving skills (Siswanto & Saefan, 2014); it was carried out in basic physics learning using the IBMR teaching model, which emphasizes on the improvement of previously-developed representational skills (Siswanto, Susantini, & Jatmiko, 2016).

Research Focus

The research focuses on analyzing the practicality and the effect of the IBMR teaching model towards students' physics problem solving skills. It specifically focuses on answering the following questions: 1) how is the practicality of the IBMR teaching model to improve students' physics problem solving skills?; such question can be answered by answering the questions: (a) how is the feasibility of the IBMR teaching model in each phase, and (b) how are students' activities in each phase of the IBMR teaching model?; and 2) how is the effectiveness of the IBMR teaching model to improve students' physics problem solving skills?; such question can be answered by answering the following questions: (a) is there any improvement of students' physics problem solving skills?, (b) what is the average of n-gain of students' physics problem solving skills?, (c) is there any difference in the average of n-gain of students' physics problem solving skills in each pair of study program groups?, and (d) how are students' responses on the IBMR teaching model?

Methodology of Research

General Background

The research was conducted in the second semester of Academic Year 2015/2016, on the student of study program of physics education, mathematics education, and mechanical engineering for basic physics courses. It emphasizes on the analysis of the practicality and the effectiveness of the IBMR teaching model to improve students' physics problem solving skills. The analysis of the practicality of the teaching model was carried out by calculating the average score of the feasibility of the learning using the IBMR teaching model in each phase and the percentage of relevant students' activities in each phase. Meanwhile, the analysis of effectiveness of the IBMR teaching model was performed by examining the difference of average scores of pre-test and post-test statistically at a = 5%, calculating the average of n-gain, examining the difference of average scores of n-gain of each pair of groups, and calculating the average of percentage of students' responses for each component.

Sample

The research was conducted in basic physics learning using the IBMR teaching model. The number of the research samples is 186 students out of total of 361 students joining lectures on basic physics in several study programs in University of PGRI Semarang of Indonesia including Physics Education, Mathematics Education, and Mechanical Engineering. The samples were selected using cluster random sampling technique. The technique is easier to do due to its application on clusters to save time (Fraenkel & Wallen, 2009). Each study program was chosen a pair (two groups) having similar problem-solving skills. The research samples of each pair of study programs included Physics Education groups of 2A and 2B (P-2A and P-2B), each of which consisted of 32 students; Mathematics Education groups of 2A and 2B (M-2A and M-2B), each of which consisted of 30 students; and Mechanical Engineering groups of 2B and 2C (E-2B and E-2C), each of which comprised 31 students.

Instruments and Procedures

The present research belonged to pre-experimental research using one group pre-test and post-test design, O1 X O2 (Fraenkel & Wallen, 2009). Before the group of students learnt about electricity and magnetism topics, students performed given pre-test on physics problem solving skills (O1). The groups of students were then given a learning on topic of electricity and magnetism using the IBMR teaching model (X) completed with such learning tools as the syllabus, teaching plan, teaching materials, and students' worksheets. The syllabus, teaching plan, teaching materials, and students worksheets were known to be valid and reliable, respectively: the syllabus (3.55: valid; 92.86%: reliable), teaching plan (3.83: valid; 95.58%: reliable), teaching materials (3.88: valid; 97.28%: reliable), and students worksheets (3.42: valid; 93.30%: reliable). After the learning process had ended, all groups of students were given a post-test (O2) on the same topic as the pre-test. Meanwhile, to obtain data of students' physics

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problem solving skills, the feasibility of the learning, students' activities, and students' responses, respectively used instruments that have also been known validity and reliability, including: test sheets on physics problem solving (3.94: valid; 98.01%: reliable), observation sheets on the feasibility of the learning(3.97: valid; 98,81 %: reliable), students' activity observation sheets(3.36: valid; 95.24%: reliable), and questionnaires on students' responses (3.64: valid; 93.33%: reliable).

Data Analysis

The data of the practicality of the IBMR teaching model were analyzed using the calculation of average scores of the feasibility of each phase of the IBMR. The feasibility is categorized good if the average of the percentage of feasibility of each phase is ^{3} 2.5; reliable based on inter observer agreement; the feasibility is considered reliable if the score of percentage agreement for the average of percentage of the feasibility in each phase is ^{3} 75% (Borich, 1994) and students' activities are said to be relevant. Students' activities are categorized if students' relevant behavior activities reach percentage of minimum 60%.

Meanwhile, the data of the effectiveness of the IBMR teaching model were analyzed using: (a) paired-sample t-test or nonparametric analysis of Wilcoxon's test (Gibbons & Chakraborti, 2011); (b) the calculation of average of n-gain with formulation: n-gain = (post-test score – pre-test score) / (maximum score – pre-test score), with the following categories: (1) high if n-gain was $\geq$ .70; (2) moderate if .70 > n-gain ≥ .30; and (3) low if n-gain was < .30 (Hake, 1998); (c) independent-sample t-test or nonparametric analysis of Mann Whitney U test (Gibbons & Chakraborti, 2011); and (d) the calculation of students' responses on the IBMR teaching model; students' responses were said to be good if the percentage of average scores of students' responses for each component was ≥ 75%.

Results of Research

The feasibility of each phase of the IBMR teaching model was observed in each meeting for all groups. Table 1 presents scores of the feasibility of each phase of the IBMR for all groups.

Table 1. The feasibility of the IBMR teaching model for all groups.

Phase	P-2A		P-2B		M-2A		M-2B		E-2B		E-2C	
	F	R (%)	F	R (%)	F	R (%)	F	R (%)	F	R (%)	F	R (%)
1	3.93	98.73	4.00	100.00	3.83	98.70	3.83	96.10	3.88	98.73	3.93	97.44
2	3.63	92.86	3.81	93.33	3.50	89.66	3.63	89.66	3.81	96.77	3.63	89.66
3	3.69	93.33	3.69	93.33	3.69	93.33	3.56	96.55	3.69	93.33	3.75	93.33
4	3.56	96.55	3.50	92.86	3.81	93.33	3.50	92.86	3.50	92.86	3.69	93.33
5	3.69	89.66	3.88	93.33	3.69	89.66	3.63	93.33	3.50	92.86	3.63	85.71

Annotation: 1 = orientation on the phenomena and the use of multiple representations; 2 = investigation; 3 = multiple representations; 4 = application; 5 = evaluation; F = feasibility; R = reliability

Table 1 displays the analysis results of practicality seen from the feasibility of each phase of the IBMR. The results indicate that each phase of the IBMR can be carried out by a lecture in each group with good and reliable category.

Activities of students' involvement in the learning process using the IBMR were also observed in each meeting for all groups. Such activities during the learning process were shown in Table 2.

Table 2. Students' activities during the learning process using the IBMR teaching model.

Students' relevant behavior activities	P-2A		P-2B		M-2A		M-2B		E-2B		E-2C	
	f	%	f	%	f	%	F	%	f	%	F	%
1. Paying attention to the explanation	23.63	76.21	22.75	71.09	22.25	74.17	23.25	77.50	20.75	66.94	21.25	68.55
2. Investigation activities	24.63	79.44	24.13	75.39	22.38	74.58	22.50	75.00	20.38	65.73	20.25	65.32
3. Involving in multiple representations	23.63	76.21	23.13	72.27	23.00	76.67	23.00	76.67	19.75	63.71	20.50	66.13
4. Doing problem solving activities	25.50	82.26	25.13	78.52	23.63	78.75	22.75	75.83	21.75	70.16	21.25	68.55

f = frequency

Table 2 reveals that in general students' activities in the learning using the IBMR teaching model were relevant. There was an improvement in each meeting of the learning. Students paid attention to the lecturer's explanation, did investigation activities with their group, involved in the display of investigation results using multiple representations, did problem solving activities, and involved in problem solving evaluation.

Figure 1 displays pre-test and post-test scores of the problem-solving skills for all groups. The grey bar indicates pre-test scores, while the shaded bars indicate post-test scores.

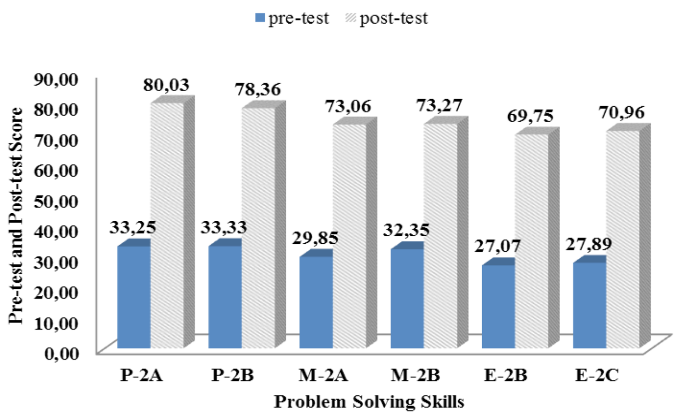

Figure 1: The average scores of pre-test and post-test on students' physics problem solving skills for all groups.

The average scores of pre-test and post-test shown by Figure 1 indicate that students' problem-solving skills on topic of electricity and magnetism for all groups show an improvement. The pre-test and post-test scores were then analyzed to find out the significance of the improvement. The analysis results of the data are presented in Table 3. Table 4, and Table 5.

Table 3. The normality and homogeneity of average scores of pre-test and post-test on students' physics problem solving skills.

Group	Score	The number of students	Average	Std. Dev	Normality, α = .05		Homogeneity, α = .05	
					Asymp. Sig. (2-tailed)	Normally distributed	Asymp. Sig. (2-tailed)	Homogeneous
P-2A	Pre-test	32	33.25	4.62	.067	Yes	.226	Yes
	Post-test	32	80.03	5.80	.059	Yes		

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Group	Score	The number of students	Average	Std. Dev	Normality, α = .05		Homogeneity, α = .05	
					Asymp. Sig. (2-tailed)	Normally distributed	Asymp. Sig. (2-tailed)	Homogeneous
P-2B	Pre-test	32	33.34	3.99	.200	Yes	.027	No
	Post-test	32	78.35	5.81	.200	Yes		
M-2A	Pre-test	30	29.84	5.04	.052	Yes	.954	Yes
	Post-test	30	73.06	5.39	.200	Yes		
M-2B	Pre-test	30	32.34	3.98	.140	Yes	.003	No
	Post-test	30	73.27	6.04	.079	Yes		
E-2B	Pre-test	31	27.00	4.67	.180	Yes	.172	Yes
	Post-test	31	69.65	4.03	.200	Yes		
E-2C	Pre-test	31	27.95	3.18	.027	No	.014	No
	Post-test	31	70.93	5.00	.144	Yes		

Table 4. The results of paired t-test towards the average scores of pre-test and post-test on students' physics problem solving skills.

Group	Score	The number of students	Average	Paired t-test, α = .05		
				t	p	Decision
P-2A	Pre-test	32	33.25	-64.33	< .001	Ho is rejected
	Post-test	32	80.03			
M-2A	Pre-test	30	29.84	-42.58	< .001	Ho is rejected
	Post-test	30	73.06			
E-2B	Pre-test	31	27.00	-73.82	< .001	Ho is rejected
	Post-test	31	69.65			

Table 5. The results of Wilcoxon test towards the average scores of pre-test and post-test on students' physics problem solving skills.

Group	Sore	The number of students	Average	Wilcoxon Test, α = .05		
				z	p	Decision
P-2B	Pre-test	32	33.34	-4.38	< .001	Ho is rejected
	Post-test	32	78.35			
M-2B	Pre-test	30	32.34	-4.93	< .001	Ho is rejected
	Post-test	30	73.27			
E-2C	Pre-test	31	27.95	-4.94	< .001	Ho is rejected
	Post-test	31	70.93			

Table 3 presents the results of normality and homogeneity tests of data of average scores of pre-test and post-test. The results of the tests were later used to determine tests for similarity of two averages such as paired t-test or Wilcoxon test as shown by Table 4 and Table 5. The results of the paired t-test towards average scores of pre-test and post-tests indicated p-value of < .001 for groups P-2A, M-2A, and E-2B. The results of Wilcoxon test (since the requirements for homogeneity were not fulfilled) towards average scores of pre-test and post-test demonstrated p-value of < .001 for groups P-2B, M-2B, and E-2C. Such results have proved that there was a significant difference between pre-test score and post-test score; since z for all groups have statistical values, the average score of post-test was greater than the average score of pre-test, meaning that there was an increase in average scores of pre-test and post-test significantly at a = 5%. This implies that there was an improvement of students' physics problem solving skills after the learning using the IBMR.

Next, analysis was carried out on the improvement of each indicator of physics problem solving skills. The average scores of pre-test, post-test, and n-gain for each indicator of students' physics problem solving skills for all groups are displayed in detail in Table 6.

Table 6. The average scores of pre-test, post-test, and n-gain for each indicator of students' physics problem solving skills for all groups.

Group	Score	Indicators of Problem Solving Skills				The Average of n-gain
		Identification	Planning	Implementation	Evaluation	
P-2A	pre-test	1.36	1.19	.89	.55	.70
	post-test	2.67	2.50	2.32	2.11	
	n-gain	.79	.72	.68	.64	
P-2B	pre-test	1.28	1.15	.86	.67	.68
	post-test	2.59	2.47	2.29	2.05	
	n-gain	.76	.71	.67	.59	
M-2A	pre-test	1.18	.97	.80	.66	.62
	post-test	2.47	2.28	2.09	1.93	
	n-gain	.71	.64	.59	.54	
M-2B	pre-test	1.30	1.16	.79	.62	.60
	post-test	2.55	2.31	2.06	1.86	
	n-gain	.73	.63	.58	.52	
E-2B	pre-test	1.09	.97	.64	.55	.59
	post-test	2.45	2.27	1.91	1.74	
	n-gain	.71	.64	.54	.48	
E-2C	pre-test	1.13	1.06	.65	.49	.60
	post-test	2.43	2.29	1.97	1.82	
	n-gain	.70	.63	.56	.53	

Table 6 presents the calculation results of the improvement of students' physics problem solving skills (n-gain) for all groups. The average scores of n-gain for all groups were .70; .68; .62; .60; .59; and .60, respectively. P-2A had high score of n-gain, while others have medium scores. Each indicator of problem solving skills showed an improvement. Problem identification showed an improvement with high category, while planning, implementation, and evaluation of problem solving showed an improvement with medium category.

The average score of n-gain was then analyzed to find out consistency (no difference) of the improvement of students' physics problem solving skills. The analysis results of the data are figured out in Table 7 and Table 8.

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Table 7. The normality and homogeneity of the average score of n-gain of students' physics problem solving skills.

Group	The number of students	n-gain	Normality, α = .05		Homogeneity α = .05	
			Asymp. Sig. (2-tailed)	Normally-distributed	Asymp. Sig. (2-tailed)	Homogeneous
P-2A	32	.70	.200	Yes	.449	Yes
P-2B	32	.68	.200	Yes		
M-2A	30	.62	.200	Yes	.048	No
M-2B	30	.60	.200	Yes		
E-2B	31	.59	.200	Yes	.028	No
E-2C	31	.60	.173	Yes		

Table 8. The results of independent t-test and Mann Whitney U test towards the average score of n-gain on students' physics problem solving skills.

Group	The number of students	n-gain	Independent t-test, α = .05		Mann Whitney U test, α = .05	
			p	Decision	p	Decision
P-2A	32	.70	.153	Ho is accepted (Consistent)	-	-
P-2B	32	.68				
M-2A	32	.62	-	-	.620	Ho is accepted (Consistent)
M-2B	32	.60				
E-2B	32	.59	-	-	.708	Ho is accepted (Consistent)
E-2C	32	.60				

Table 7 details the results of normality and homogeneity tests of the average of n-gain as a requirement for analysis of independent t-test or Mann Whitney U test as presented in Table 8. The independent t-test and Mann Whitney U tests results in p-value of .153 for P-2A and P-2B; .620 for M-2A and M-2B; and .708 for E-2B and E-2C. All p-values were > .05, meaning that there was no significant difference of the average of n-gain for each pair (on total three pairs), between P-2A and P-2B, between M-2A and M-2B, and between E-2B and E-2C. In other words, such results showed a consistency of the improvement of students' physics problem solving skills.

After the learning, students were asked to give responses to the learning using the IBMR. Students' responses are related to: the implementation of the learning process, clarity and ease in multiple representations and problem solving, and students' interest on the IBMR teaching model. Students' responses on the learning using the IBMR can be seen in Table 9.

Table 9. Students' responses to IBMR teaching model.

Component of Responses	P-2A	P-2B	M-2A	M-2B	E-2B	E-2C
	Yes(%)	Yes(%)	Yes(%)	Yes(%)	Yes(%)	Yes(%)
1. The novelty of learning process						
e. The way a lecturer teaches	96.88	93.75	100.00	96.67	96.77	90.63
f. Language and contents of textbooks	90.63	93.75	90.00	90.00	87.10	84.38
g. Language and contents of students' worksheets	84.38	84.38	93.33	93.33	87.10	84.38
h. Learning activities	96.88	87.50	100.00	100.00	96.77	90.63
i. Learning situations	93.75	93.75	96.67	96.67	90.32	90.63

Component of Responses	P-2A	P-2B	M-2A	M-2B	E-2B	E-2C
	Yes(%)	Yes(%)	Yes(%)	Yes(%)	Yes(%)	Yes(%)
Average	**92.50**	**90.63**	**96.00**	**95.33**	**91.61**	**88.13**
2. Clarity in delivering multiple representations						
a. Verbal	90.63	93.75	93.33	93.33	90.32	96.67
b. Pictorial	87.50	87.50	93.33	90.00	87.10	96.67
c. Graphical	87.50	90.63	90.63	86.67	80.65	86.67
d. Math	87.50	87.50	87.50	93.33	90.32	93.33
Average	**88.28**	**89.84**	**93.33**	**90.83**	**87.10**	**93.33**
3. Ease in implementing multiple representations						
a. Verbal	87.50	87.50	90.00	90.00	87.10	93.33
b. Pictorial	90.63	90.63	86.67	83.33	83.87	86.67
c. Graphical	93.75	90.63	86.67	83.33	77.42	83.33
d. Math	93.75	93.75	93.33	93.33	90.32	93.33
Average	**91.41**	**90.63**	**89.17**	**87.50**	**84.68**	**89.17**
4. Clarity in delivering problem solving						
a. Identification	90.63	87.50	93.33	93.33	90.32	93.33
b. Planning	90.63	90.63	86.67	86.67	83.87	86.67
c. Implementation	96.88	87.50	90.00	86.67	83.87	86.67
d. Evaluation	93.75	93.75	90.00	90.00	87.10	90.00
Average	**92.97**	**89.84**	**90.00**	**89.17**	**86.29**	**89.17**
5. Ease in problem solving						
a. Identification	87.50	87.50	86.67	86.67	83.87	86.67
b. Planning	90.63	90.63	83.33	83.33	80.65	83.33
c. Implementation	90.63	87.50	93.33	83.33	87.10	83.33
d. Evaluation	90.63	87.50	90.00	83.33	87.10	90.00
Average	**89.84**	**88.28**	**88.33**	**84.17**	**84.68**	**85.83**
6. Ease in performing evaluation						
Test for representation	84.38	87.50	83.33	83.33	80.65	86.67
Test for problem solving	84.38	81.25	80.00	80.00	77.42	80.00
Average	**84.38**	**84.38**	**81.67**	**81.67**	**79.03**	**83.33**
7. Interest on the IBMR teaching model						
a. Subsequent materials	93.75	100.00	100.00	96.67	96.77	93.33
b. Materials of other lectures	96.88	96.88	93.33	93.33	90.32	86.67
Average	**95.31**	**98.44**	**96.66**	**95.00**	**93.55**	**90.00**

Table 9 demonstrates that students gave good responses on the learning using the IBMR learning method. The average of students' responses was > 75%., proving that students support the learning process using the IBMR.

Discussion

The practicality and the effectiveness of the teaching using the IBMR indicated that the model supports students of bachelor programs in teaching basic physics to improve their problem-solving skills. The practicality of the IBMR was underlain by the fact that each phase was carried out by the lecturer well and students' activities were relevant to each phase of learning. Meanwhile, the effectiveness of the model is based on the learning

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process and outcomes (Dunkin & Biddle, 1974); students actively participate in the learning (Eom, Wen & Ashill, 2006) and learning outcomes are improved due to good responses on the learning (Zimmerman & Schunk, 2012).

The results of the research revealed that each phase of the IBMR teaching model can be performed by a lecturer in each group well as presented in Table 1. This shows that each phase of the model expressed in a lecture can be well implemented. Such results fulfill a criterion of the practicality of a model: applicable in field (van den Akker, 1999; Nieveen, 1999). Meanwhile, the results of observation during the learning process indicated that students' activities were relevant in each phase of learning, as shown by Table 2. Students actively participated in learning, particularly in phases of orientation, investigation, multiple representation, application on problem solving, and evaluation, however, the implementation of the learning dealt with difficulties in assembling devices. However, the lecturer can overcome such constraint by guiding students to do it properly. This implies that the constraint was not that significant. This fact is in line with group management theory (Slavin, 2006) stating that the implementation of learning without constraints is not always better; a lecturer should apply certain techniques to overcome the constraints found.

The improvement of students' physics problem solving skills can be seen from their problem-solving skills on topic of electricity and magnetism obtained from the calculation of scores of pre-test and post-test. Figure 1 illustrates that prior to the learning using the IBMR, students had low problem-solving skills. Their average scores were below standard score of 33.25 on score range of 0-100 for P-2A; 33.33 for P-2B; 29.85 for M-2A; 32.35 for M-2B; 27.07 for E-2B; and 27.89 for E-2C. This probably happened because students were not used to doing activities of physics problem solving as required in the IBMR teaching model, which include: problem identification, problem solving planning, implementation of problem solving, and evaluation.

The implementation of the IBMR teaching model exerted an influence on the improvement of students' physics problem solving. Figure 1 shows positive results of the implementation. Their average score of physics problem solving skill showed an increase into 80.03 on score range of 0-100 for P-2A; 78.36 for P-2B; 73.06 for M-2A; 73.27 for M-2B; 69.75 for E-2B; and 70.96 for E-2C. The increase in all groups was statistically significant at significance level of 5%, as indicated by Table 4 and Table 5.

An improvement in indicators of students' physics problem solving skills was also found with the medium-categorized average score of n-gain as shown by Table 6. Students made improvement in identifying problems, designing problem solving, implementing, and evaluating the problem solving. They had more capabilities of solving physics problems after being treated with the IBMR teaching model. This was so probably because in the learning using the IBMR, they were equipped with representational skills to solve problems. Representation is the key to solve problems and it helps understand concepts, solve problems, and propose problems (Jonassen, 2005; Hinrichs, 2004; Bodner & Domin, 2000; Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, 2005; Prain, Tytler, & Peterson, 2009; Rosengrant, Van Heuleven, & Etkina, 2006; Dancy & Beichner, 2006; Portoles & Lopez, 2007; Nguyen, Gire, & Rebello, 2010; Maries, 2013; Sinaga, Suhandi, & Liliasari, 2014; Haratua & Sirait, 2016; Huda, Siswanto, Kurniawan, & Nuroso, 2016).

Students' abilities in problem identification showed an improvement after being treated using the IBMR teaching model. Such improvement can be seen from their ability in writing quantity known in the problem, writing problems to be solved, rewriting problems with the aids of related formats and information (problem understanding). Problem identification is an important component in physics problem solving. Basically, physics problem solving involves two procedures: problem representation and problem solving. Successful problem solving cannot be achieved without proper problem representation (Bodner & Domin, 2000; Jonasses, 2005; Milbourne & Wiebe, 2017; Bimba, Idris, Mahmud, Abdullah, Abdul-Rahman, Bong, 2013; Berge & Danielsson, 2013; Yeo & Tan, 2014). Physics problem identification determines procedures of problem solving planning, implementation of problem solving, and evaluation. The IBMR teaching model supports improvement of problem identification using multiple representations. Students' understanding of physics problems can be improved by guiding students use representation (Bimba, Idris, Mahmud, Abdullah, Abdul-Rahman, Bong, 2013). Students made use of multiple representation to understand problems to succeed in solving physics problems.

Students' abilities in planning, implementing and evaluating problem solving showed an improvement along with the improvement of their abilities in identifying problems, as presented in Table 6. Students were able to construct physics problem solving planning by identifying concepts, principles, formulation, and/or physics laws, as well as determining appropriate mathematical equations. They could implement the planning through substitution of the known value of quantity into mathematical equations and perform mathematical calculation. In addition, they were able to evaluate the problem solving by checking the suitability of their answers with problems and by checking the units.

Tests for similarity of two averages of n-gain on students' physics problem solving skills as shown by Table 8 result was no significant difference for n-gain scores in each pair of groups (between P-2A and P-2B, between M-2A and M-2B, and between E-2B and E-2C). This proved the consistency of the improvement of students' problem-solving skills after being treated with the IBMR. Also, the IBMR contributed to similar effects and influences on the improvement of students' physics problem solving skills for each pair of groups.

The phase which trained students to apply multiple representations for physics problem solving skills in the IBMR teaching model is the phase of application. Such phase explicitly gives opportunities to students to solve problems by applying multiple representations. Supportive learning environment and guidance of multi representations can help solve physics problems (Maries, 2013). In the teaching of basic physics using the IBMR model, students are guided to apply multiple representations in physics problem solving. External representation can describe human knowledge, facilitate complex cognitive processes in problem solving, understand and explain problems, reduce complexity of problems, constrain unnecessary cognitive works, help plan more effective and efficient solutions (Vekiri, 2002; Larkin, 1989; Scaife & Rogers, 1996; Bauer & Johnson-Laird, 1993). Applying multiple representations is useful for students in understanding and problem solving (Dufresne, Gerace, & Leonard, 1997; Van Heuleven, 1991; Rosengrant, Van Heuleven, & Etkina, 2006).

Multiple representations help students understand and solve problems with various approaches (Jatmiko et al., 2018). Students have the opportunity to use various means to deal with problems, preventing them from directly using and manipulating mathematical equations to solve physics problems. Solving problems with the mathematical way does not guarantee understanding of physics concepts (Ibrahim & Rebello, 2013; Etkina, Warren, & Gentile, 2006). Such fact is in accordance with the theory of cognitive constructivism stating that students will actively involve in the process of obtaining information and constructing their own knowledge (Piaget, 1964; Moreno, 2010; Simatwa, 2010).

Table 9 indicates that after the learning process, the students felt the presence of the novelty in the physics learning process in addition to the novelty of activities and learning environment. Activities of the investigation, multiple representations, and problem solving are important keys to get the good responses. For that reason, they will be excited if the teaching model is implemented in other lectures.

The implementation of the IBMR teaching model was proved to be practical and effective to improve physics problem solving skills of the students of bachelor programs on the learning of basic physics. Students showed an improvement in their problem solving for concepts of electricity and magnetism. The finding of the presence of such improvement after being treated with the IBMR teaching model was in line with Vygotsky's social constructivist theory which has four main implications: social learning, zone of proximal development (ZPD), scaffolding, and cognitive apprenticeship (Slavin, 2011). Social learning refers to students' learning through interaction with others; ZPD is the distance between the actual developmental level as determined by independent problem solving and the level of potential development under more capable peers; scaffolding relates to sufficient support during the learning process; and cognitive apprenticeship means students' gradual way to achieve expertise under the guidance of lecturers or more capable peers.

Conclusions

The results of research and discussion concluded that the teaching of basic physics using the IBMR on topic of electricity and magnetism to improve students' physics problem solving skills was proved to be: 1) practical (applicable in learning), shown by (a) the implementation of each phase of the model by a lecturer in good and reliable categories, and (b) relevant percentage of students' activities in each phase, and 2) effective, shown by (a) the significant increase in physics problem solving skills at a = 5%, (b) average n-gain which moderate categorized, (c) average n-gain not different or consistent for each pair of groups, and (d) good-categorized students' responses on each component of teaching. The development of physics problem solving skills through the IBMR teaching model is expected to support students to achieve success in the future. They need guidance and pedagogical support of highly qualified lecturers to become accustomed to solving problems scientifically. The implication of this research is that the IBMR teaching model can be used as an alternative to overcome the low level of physics problem solving skills of bachelor programs' students in the basic physics course. To strengthen the result of this research, it is necessary to do research in various education levels and countries.

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