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Multi-representation based on scientific investigation for enhancing students' representation skills

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Abstract. This research aims to implementation learning physics with multi-representation based on the scientific investigation for enhancing students' representation skills, especially on the magnetic field subject. The research design is one group pretest-posttest. This research was conducted in the department of mathematics education, Universitas PGRI Semarang, with the sample is students of class 2F who take basic physics courses. The data were obtained by representation skills test and documentation of multi-representation worksheet. The Results show gain analysis $\langle g \rangle$ value of .64 which means some medium improvements. The result of t-test ($\alpha = .05$) is shows p-value = .001. This learning significantly improves students representation skills.

5 **Introduction**

Representation is something that represents, describes or symbolizes an object or process [1, 2]. Representing the same concept using different formats is multi-representation. In the study of physics, the mastery of concepts relates to the use of various scientific languages, such as verbal, visual, symbol and equation, body gestures, role-playing, presentations, etc. that enable students to study physics through the development of mental thinking skills [3].

Multi-representation helps students understand the concept. The results showed that most of the students came to universities with non-scientific ideas, but the multi-representation applied in the learning environment had a positive effect on student ideas [4]. It shows important representations used in physics learning especially in helping to understand concepts and convey scientific ideas.

Students will learn physics more effectively and efficiently when using multiple representations [5-9]. However, students are not successful in transforming between representations, especially oral (verbal representation) to other representations [10]. Students are not able to use multi-representation in understanding the concepts of physics, and it becomes a matter of understanding [11]. It takes effort so that students can use multi-representation in physics learning.

Scientific investigations contribute positively to representation skills [12]. Students have better multi-representation skills in physics learning after conducting a scientific investigation. In addition, students are able to create and connect between representations after conducting a scientific investigation. Scientific investigations support the understanding of student concepts, experiments, and scientific methods [13]. Students have the freedom to choose procedures in conducting experiments [14].

Based on the importance of multi-representation and the role of scientific investigation, we have designed a learning model for enhancing representational skills. We call this model of Investigation Based Multiple Representation (IBMR). The IBMR model was developed as a physics learning

intervention program. In the IBMR learning model, lecturers will spend more time focusing on conceptual and problem-solving aspects. It aims to make students understand concepts and motivated to engage in problem solving [15]. Understanding can be done by way of modeling the physics phenomena [16]. Models can be used to describe and explain existing physics phenomena, as well as modeling of physics phenomena can be used to help solve physics problems [17, 18].

The IBMR learning model is supported by constructivist learning theory. Constructivist learning theory views learning as an active process by individuals actively in building knowledge based on personal experience when interacting with others and the environment [19]. Students will gain an in-depth understanding through a multi-representation process based on the results of the investigation.

The IBMR learning model has five phases. Phase 1: Student orientation to phenomena and the use of multi-representations. Phase 2: Investigation. Phase 3: multi-representation. Phase 4: application. Phase 5: evaluation.

In this paper, we will describe the implementation of the IBMR learning model for enhancing the representation skills of physics concepts, especially in magnetic field subjects. Magnetic field material was chosen because many students are having difficulty understanding the concept even though it has been a lecture. In addition, many students experience misconceptions in the representation of field line concepts [20].

2. Methods

This research conducted in Universitas PGRI Semarang, the population of all grade 2 in the department of mathematics education in the academic year 2015-2016. The sample in this research is the student of class 2F. The sampling technique is cluster random sampling. The research design is one group pretest-posttest [21]. Methods of data collection in this research is the representation skills test and documentation of multi-representation worksheet. Representation skills tests are performed before and after the lesson, while the worksheet documents are used during the learning process and are collected after the lesson. The data analysis consists of two phases of initial and final stages. The initial data analysis consisted of normality test and homogeneity test. The final data analysis consists of paired t-test (or Wilcoxon-test) and gains score $\langle g \rangle$. Gain score $\langle g \rangle$ is categorized as "High" if $\langle g \rangle \geq .7$, "Medium" if $.7 > \langle g \rangle \geq .3$, and "Low" if $\langle g \rangle < .3$ [22].

3. Result and Discussion

Before intervention learning with IBMR models, students were given pretest representation skills. Learning model of IBMR is implemented as an intervention program, and ends with a posttest. Pretest, posttest, and skill representation data analysis are presented in Table 1.

Table 1. Score of Representation Skills and Results Analysis

	Score of Representation Skills				Normality	Homogeneity	Wilcoxon-test
	Min	Max	Average	Std. Dev.	($\alpha = .05$)	($\alpha = .05$)	($\alpha = .05$)
Pre-test	6.00	16.00	12.50	2.29	p-val= .070		
Post-test	17.00	22.00	19.83	1.34	p-val= .086	p-val= .021	p-val= .001

The result of the test of normality of pretest score got p-value = .070 and normality test of posttest score got p-value = 0.086. If both p-values are compared with $\alpha = .05$, then $\alpha < p$ -value, so the pretest and posttest scores are normally distributed. The homogeneity test results obtained p-value = .021, so the data is not homogenous ($.05 > .021$). Because the data were not homogeneous, the data analysis was performed by the Wilcoxon test ($\alpha = .05$). The data analysis using Wilcoxon test is obtained p-value = .001 so that $\alpha > p$ -value and the decision can be made that there is the significant difference between representation skills before and after learning using multi-representation based on investigation models. This shows that learning by multi-representation based on investigation models significantly influences student representation skills.

The average score of student representation skills increased from 12.50 to 19.83. The analysis using gain score was obtained $\langle g \rangle = .64$, with the criterion "medium". This shows an improvement in representational skills of students having moderate criteria, after being given a multi-representation study based on the investigation. The average gain score for each concept is presented in Table 2.

Table 2. The Average of gain $\langle g \rangle$ Score

Concept	Representation		Score Averages		$\langle g \rangle$	
	Source	Targets	Pre-test	Post-test	Score	Criteria
Magnetic fields	Image	Image	1.63	2.58	.70	High
		Verbal	1.55	2.37	.56	Medium
Magnetic field of a long wire	Image	Verbal	1.53	2.47	.64	Medium
		Image	1.40	2.50	.69	Medium
Magnetic forces	Verbal	Image	1.50	2.40	.60	Medium
		Math	1.70	2.57	.67	Medium

Table 1 and Table 2 show the effectiveness of multi-representation learning models based on investigations for enhancing student representation skills, especially on magnetic field subjects. The student representation skill increases with the high and medium category. The increase is due to scientific investigation process and multi-representation in learning activities, with guided worksheets. Students experiment, then the results are written and presented with multi-representation. The process is able to train students to build a representation of the results of scientific investigations. This is one of the characteristics of IBMR models. Stages of IBMR models that trace the representation skills of magnetic fields are presented in Table 3.

Table 3 shows the phases of the IBMR learning model, lecturer activity, student activity, and representation building phases. Lecturers initiate learning by displaying magnetic field phenomena and lecturers explain multi representation, as well as its usefulness. After that, the lecturer guides the students to conduct a scientific investigation of the phenomena that have been presented. Investigations will assist students in gaining knowledge scientifically, thus supporting the understanding of physics concepts. This shows that the scientific investigations help students understand the concept [13]. Understanding the concept is increasingly accessible from the multi representation presented by the students. Students use verbal, image, and math representations to present the same concept.

The learning phase that can traverse representational skills is supported by Johnson-Laird's cognitive framework, which highlights three main categories of mental representation. First, the mental representation of propositions consists of a series of symbols, such as equations, formulas, numbers, and definitions of abstract and meaningful syntactic structures when not integrated in context. Second, the mental model built by perceptions or imaginations and analogical representations of real-world situations, is only useful to the person who produces it, and is tentative. All can be discarded or perfected with greater knowledge and exposure, and familiarity with the situation under consideration. Third, mental images based on observations and experiences from the real world, coherent and unified representations of events or objects from a particular point of view in which each element clearly occurs only once with all concomitant elements [23].

Table 3. Phase of the IBMR Model and Phase of Building Representation

Phase	Lecturer Activity	Student Activity	Phase of Building Representation
Student orientation on phenomenon and use of multi representation	Presenting physics phenomena: the iron sand around the wire is electrified Guiding students in identifying physics concept: electric current, wire length, voltage source, magnetic field Facilitate students to present the concept of magnetic field around the wire with multi-representation Explaining the learning objectives	Pay attention to examples of physics phenomenon Identify the concept Present a physics concept with multi-representation Pay attention to the explanation of learning objectives	Identify the concept Build internal representation based on initial knowledge Presenting with multiple initial representations (external representations based on initial knowledge)
Investigation	Inform the needs of scientific investigations: worksheets, tools, and experimental materials Guiding students to design and conduct group experiments	Preparing for scientific investigation needs Designing and executing experiments	Strengthening or rebuilding internal representation based on scientific investigation
Multi-representation (verbal, image, and math)	Guiding students to analyze experiment data and present it with multi-representation Guiding students to analyze multi representation and test based on initial multi-representation	Analyze data of experimental results and present with multi-representation Analyze multi-representation Test multi-representation	Present a final multi-representation (Strengthening or revising external representations based on scientific investigations)
Application	Provide problems according to the concept of physics that has been represented Guiding problem solving with multi-representation	Multi-representation problem solving with identification, planning, execution, and evaluation.	Phase of application for physics problem solving
Evaluation	Facilitating students to communicate results Guiding students to reflect on the process and result of multi-representation usage.	Communicate the results of problem solving Reflecting on process and problem-solving results with multi representation.	Phase of application for physics problem solving

In addition, multi-representation studies based on investigation also adapt the physics modeling. The physicists convey some general ideas about the model, namely: 1) the model is a simplified version of an object or process under study; 2) the model can be descriptive or clear; the model is clearly based on analogies-related objects or processes to more familiar objects or processes; 3) the model has predictive power; 4) power model prediction has its limitations [16]. An example of the

work of students using worksheets in representing physics concepts based on the results of the investigation is presented in Figure 1 and Figure 2.

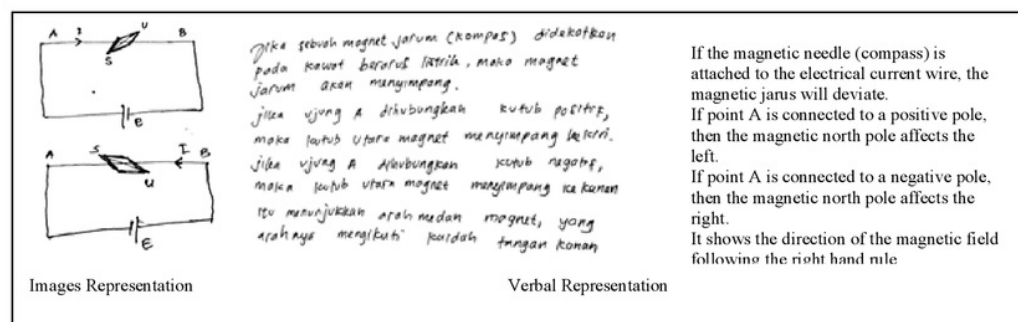


Figure 1. Result of Images and Verbal Representation by Student

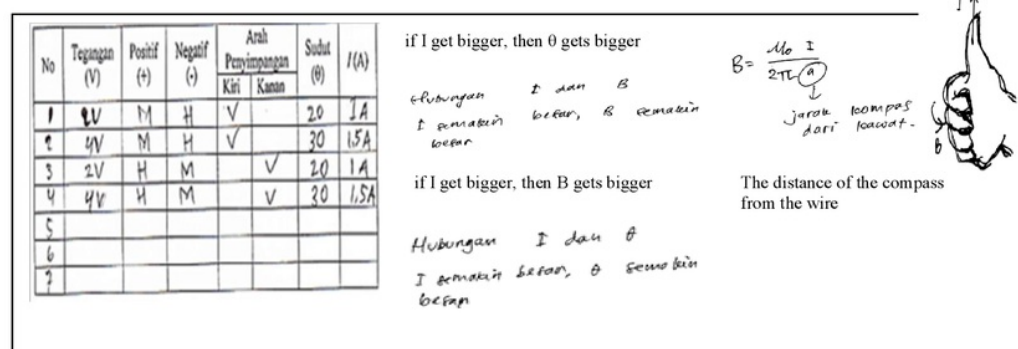


Figure 2. Results of Student Work in Worksheet

Figure 1 and Figure 2 shows the process of working students building representations based on investigations. Students represent the image, verbal, and math. The student draws and explains verbally the direction of the magnetic field around the straight-wire electrical current. It trains student representation skills. In addition, it can also help students build an understanding of the situation deeply.

4. Conclusion

Based on the result of the discussion it is concluded that physics learning using multi representation model based on investigation (the IBMR Model) on magnetic field subjects can enhancing student representation skill. Students experience improved representation skills in the medium category. Students are able to represent the concept of magnetic field in verbal, images, and math.

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