The effects of multiple representations-based learning in improving concept understanding and problem-solving ability

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Abstract. The objective of this research was to find out effects of multiple representations-based learning model in improving concept understanding and problem solving in electricity subject. This research used pre-test and post-test quasi-experiment design with control group. Samples were 184 respondents containing of 92 samples respectively for experiment and control groups. Data were collected using multiple choice and essay test. Analysis of data was done by using normality test, homogeneity test, independent sample t-test. The result showed that there was a significant difference post-test and normalized gain (n-gain) of concept understanding and problem-solving ability between experiment and control group. The application of multiple representations-based learning in electricity subject had positive effect in improving concept understanding and problem solving compared to traditional model being used so far.

Keywords: Concept Understanding, Multiple Representations, Problem Solving.

1. Introduction

Physics involves understanding and application of physics concepts to solve problems. This is supported [1,2] which stated that Concept understanding has an important role and it is unseparated part in physics problem solving. The similar notion is stated by [3] that concept understanding can help problem solving and problem solving will strengthen their conceptual understanding, procedural fluency, strategic competence, productive disposition and adaptive reasoning abilities. Physics concept, especially on abstract subject can be displayed at multiple representation levels, i.e macroscopic, microscopic, and symbolic [4]. Macro and tangible shape more easily understood by students, because it can be seen, touched and felt [5], like observing the movement of the needle on ammeters in Ohm's law; Microscopic: atoms, positive charge, negative charge (electron), and electric current; and symbolic the representation formulae and equations. Macro and symbolic form of the most often discussed in class compared to forms submikro [5,6]. Electric charge is very small, so can not be observed, because its shape can not be seen, touched and felt. Not only difficult to understand the concept of micro, but also difficult to make the connection between macro, micro, and symbolic.

Teaching and learning of abstract and complex materials in physics should involve concept understanding and problem solving integrally. An Emphasizing on one of either concept understanding or problem solving should be avoided [7]. In a matter of learning abstract lecturers should be able to direct students on understanding the relationship between macro, micro and symbolic. Therefore it is necessary learning design with a strategy that is appropriate to the characteristics of the material and
objectives to be achieved. Electricity material is both abstract and complex while the objective to pursue is concept understanding and problem solving, so that the most suitable learning model is multiple representations-based learning. It learning model can help students to improve their understanding and to think about abstract concept. Meanwhile, [7] stated that not only different representation application improves concept understanding, but it also improves problem solving ability and critical thinking skill. Using different representations in learning physics allows students to describe, explain, manipulate, and be able to predict problems.

A good representation is able to express something explicitly, make a problem clearer, show existing natural limits, it has certain limitations, and it is complete and efficient. According to [8, 9], benefits for students of using representations in learning are: 1) each used representation is able to show particular aspects of domain to learn; 2) representation is able to limit other representation interpretation; 3) by interpreting representations, learners are able to build abstraction that allows deeper understanding to a domain. In addition, van der Meij & de Jong recommend students who use representation in learning that they should pay attention to: 1) understanding syntax of each respective representation; 2) understanding which part a domain is represented; 3) being able to relate between a representation to another representation; 4) being able to translate between interpretations.

Multiple representations can be used to describe an observed event or phenomenon in physics with varying presentations so that a difficult and abstract concept will be easier to understand. Multiple representations can change a representation form to another representation form [10]. Students need to understand varying representation forms and be able to translate varying different representation forms into other representation forms by their knowledge. According to [11], a learning environment with multiple representations has three main functions. The first function is using representation to obtain additional information or to support existing cognition process and to be mutually complementary. Second, representation can be used to limit interpretation which may occur. Third, representation can be used to motivate students in building deeper understanding. Ainsworth also proves that multiple representations play three main roles: being mutually complementary, explaining uncommon representation, and helping students to arrange deeper understanding about a topic. Meanwhile [12] stated that three types of representations which may be used in parallel: concrete, pictorial, and symbolic representations.

Using different representations in learning and teaching can help students in problem solving [13,14]. Other researchers on the same topic, such as [15] found that using multiple representations in learning can enhance concept mastery, generic science skills, and critical thinking; while [6] found that learning with multiple representations to improve mental model of students.

Some physics education research results show that students experience difficulties in understanding basic physics concepts [16,17], electricity and magnetism [18,19]. These difficulties are caused by abstract and complex natures of electricity material and it requires mathematics skill [19]. In learning, the abstract material teachers rarely show the form of micro and how the relationship between macro, micro and symbolic. Inability to visualise the micro form, such as electric charge, electric current, electric potential will make it difficult to understand the electric field, the electric force, electric potential, and Kirchoff laws. Difficulty in understanding these problems make students frustrated, bored, and ended up with memorising the facts [5].

The strategy used by researchers in multiple representations based learning only to improve understanding of concepts, critical thinking, and mental models. The problem often faced by students is to understand the concept and how to apply these concepts to solve problems. Concepts and problem solving in physics is an inseparable part. Thus the required specific strategies in multiple representations based learning, namely: recognizing concept through analogy, explaining concept with some representation, applying concepts following solution examples, and looking back learning activity results through self-reflection.

Analogy is a comparison between two concepts of phenomena having common conformities [20]. Using analogy to explain abstract and complex concepts is not only improving deeper concept
understanding, but it also able to overcome misconception [21,22] and knowledge limitation on the target concepts [23]. Concepts have already been recognized by analogy, and then they are explained verbally, pictorially, and symbolically. Solving the problem followed the example of solution could guiding students to solve the problems of abstract and complex.

The objective of this research was to find out the effects of multiple representations to concept understanding and problem solving. This objective is relevant to the following research questions: 1) What are the effects of multiple representations to concept understanding and problem solving? ; 2) Is the multiple representations more effective in improving concept understanding and problem solving in electricity subject compared to traditional model?.

2. Method

The population of the study is consisted of candidate teachers who attended Lampung University (UNILA), Islamic Institute (IAIN), and Muhammadiyah Metro University (UMM), Education Faculty of basic physics. Based on initial results, there is no difference between the initial ability of students in UNILA, IAIN, and UMM. This research used quasi-experiment design and pretest-posttest control group (Figure 1). The groups received the same material and the same length of time and they were taught by the same researchers. Throughout the 8 weeks, while the electric unit subject consists of static and dynamic.

Participants were 184 students of physics education and teaching containing of 92 samples for both experiment and control groups respectively. Experiment group was taught with multiple representations, while control group was taught with traditional learning model, such as the direct telling and asking-answering [24].

Concept understanding data were collected using Conceptual Understanding Test (CAT) with open-ended questions adopted from a test model developed by [25,26] to make the necessary adjustment, such as the suitability of the language and subjects. The designed conceptual understanding test consisted of 6 indicators; interpreting, exemplifying, classifying, inferring, comparing, and explaining, with 12 items of questions. For each question, students selected one of most correct answer and explained their selected answer into a provided space. If there was no correct answer found, students were allowed to use empty space to explain. Problem solving test was conducted by using essay test developed by the researchers themselves, the test contained of 5 problems representing all of electricity subjects. The instruments of concept understanding and problem-solving test were tested for their validities and reliabilities to those students who passed basic physics tests. The test results suggested that the instruments were valid and reliable. Test instruments were given before and after treatments for both of experiment and control groups.

Data analyses were conducted descriptively and inferentially. Descriptive analysis was conducted through transcripts and categorizing concept understanding, problem solving ability. Inferential analysis with using normality test, homogeneity test, independent sample t-test was conducted to find out differences of concept understanding and problem-solving pretest score results between experiment and control groups. Differences of posttest and normalized gain scores of concept understanding and problem solving ability between experiment and control groups calculated by using independent t-test with 0.05 significance level. Average normalized gain score was estimated with the following formula:

\[
<g> = \frac{\text{post test score} - \text{pre test score}}{100 - \text{pre test score}} \quad [27].
\]
<g> score criteria were composed as the following: high <g> >0.7; moderate <g> when 0.3 < <g>; and low <g> when <g> ≤ 0.3. Difference analysis between pretest and posttest was conducted by using paired t-test. Independent and paired t-test were estimated by using SPSS V.17.0 software, while <g>, averages of retest, posttest, and students’ perceptions to the model were estimated by using Excel software.

3. Results and Discussion
Pretests were conducted before learning activities commenced at each of the group. The differences of pretest results between experiment and control groups were analyzed using Mann-Whitney test (independent t-test). Mann-Whitney test was conducted because pretest data of conceptual understanding and problem-solving ability from experiment and control groups were not distributed normally. Results of descriptive statistic test and independent t-test between experiment and control groups are presented in Table 1. It shows that initial test scores between experiment and control groups are not significantly different. Thus, both groups have similar initial abilities in concept understanding and problem-solving ability. The result of t-test will be show in Table 1.

Table 1. T-test result differences of initial abilities of concept understanding and problem solving ability between experiment and control groups.

| Type of Test Group | n  | x  | s   | p   | z         |
|-------------------|----|----|-----|-----|-----------|
| Pretest of Conceptual Understanding | Exp. | 92 | 36.00 | 4.78 | 0.213 -1.244 |
| Control           | 92 | 35.28 | 4.64 |     |           |
| Pretest of Problem-Solving Ability | Exp. | 92 | 25.87 | 4.98 | 0.533 -0.623 |
| Control           | 92 | 26.22 | 4.39 |     |           |

Difference is not statistically significant, p > 0.05

Pretest-posttest and n-gain results of electricity subject concept understanding of experiment and control groups are presented in Figure 2.

Figure 2 shows that the average of posttest results of experiment groups is higher (70.24) than control group (53.83). Normalized gain of concept understanding of experiment group is higher (61.29%) than
control group (40.64%). Normalized gain results for both experiment and control groups belong to moderate category.

Analysis of data was done by Mann-Whitney test show that there difference posttest concept understanding between experiment and control group (Table 2). There are also differences in the normalized gain between experimental and control group.

**Table 2. Differences of posttest and normalized gain between experiment and control groups.**

| Type of Test                   | Group    | n  | $\bar{x}$ | s   | P     | z   |
|-------------------------------|----------|----|-----------|-----|-------|-----|
| Posttest of conceptual        | Experiment | 92 | 70.24     | 8.52| <0.001| -5.896|
| understanding                 | Control  | 92 | 61.29     | 8.78|       |     |
| Normalized gain of conceptual | Experiment | 92 | 53.61     | 13.77| <0.001| -5.627|
| understanding                 | Control  | 92 | 40.60     | 12.95|       |     |

Difference is statistically significant, $p < 0.05$

Based of data analysis (Table 2) show that multiple representations is more effective in improving concept understanding compared to traditional model. The difference test results of each indicator is shown in table 3.

**Table 3. Difference test results of each indicator of concept understanding.**

| Indicators         | Posttest difference between experiment and control group | N-gain difference between experiment and control groups |
|--------------------|---------------------------------------------------------|-------------------------------------------------------|
|                    | $P$               | $Z$     | $P$     | $Z$     |
| Interpreting       | <0.001            | -3.283  | < 0.001 | -3.293  |
| Explaining         | 0.651             | 0.651   | < 0.001 | -4.684  |
| Classifying        | <0.001            | -4.671  | 0.195   | -2.666  |
| Exemplifying       | <0.001            | -5.744  | < 0.001 | -6.159  |
| Comparing          | <0.001            | -4.934  | < 0.001 | -0.903  |
| Inferring          | <0.001            | -4.085  | < 0.001 | -0.844  |

Table 3 shows significant differences on all indicators of concept understanding posttest between experiment and control group ($p < 0.05$), except explaining indicator ($p > 0.05$). Normalized gain differences of concept understanding indicators between experiment and control groups are seen in almost all indicators except classifying indicator ($p > 0.05$).

The averages of pretest, posttest, and normalized gain of problem solving in electricity subject are presented in Figure 3.

![Figure 3. The averages of pretest, posttest, and n-gain of problem solving.](image)
Figure 3 shows that the posttest average of problem-solving ability in experiment group is higher (70.26) than in control group (52.96). Normalized gains of problem solving abilities in experiment and control groups respectively belong to moderate categories. There is a significant normalized gain difference of problem-solving ability (p < 0.00) between experiment and control groups (Table 4).

Table 4 shows significant differences posttest between experiment and control group (p < 0.05). It means that multiple representations-based learning with REAL strategy is more effective in improving problem solving ability than traditional model being used so far in basic physics learning.

Table 4. Difference descriptive statistic and t-test results of concept understanding between pretest and posttest in experiment group.

| Test of differences | Experiment | N  | Number  | Control | N  | Number  | P     | z       |
|---------------------|------------|----|---------|---------|----|---------|-------|---------|
| Posttets of problem solving abilities between experiment and control groups | Experiment | 92 | 70.26   | Control | 92 | 52.96   | <0.001 | -9.541  |
| N-gain of problem-solving abilities between experiment and control groups | Experiment | 92 | 59.79   | Control | 92 | 36.11   | < 0.001 | -9.53   |

Difference is not statistically significant, p < 0.05

Table 5 shows significant differences of problem-solving abilities indicators posttest between experiment and control groups (p < 0.05). It also shows normalized gain of problem-solving ability between experiment and control groups.

Table 5. Difference of posttest, and normalized-gain (n-gain) of problem-solving indicators.

| Indicators   | Difference of posttest between experiment and control groups | Difference of normalized gain between experiment and control groups |
|--------------|-------------------------------------------------------------|-------------------------------------------------------------------|
|              | P     | Z         | P     | Z         |
| Set up model | <0.001 | -7.443    | < 0.001 | -5.973    |
| Analysis     | <0.001 | -7.056    | < 0.001 | -5.905    |
| Problem      | <0.001 | -5.032    | < 0.001 | -3.843    |

Difference is statistically significant, p < 0.05

Statistic test results show significant differences posttest of concept understanding between experiment and control group. Difference also on normalized gain concept understanding between experiment and control groups. There are concept understanding improvements at both groups, but multiple representations-based learning with “REAL” strategy is more effective in improving concept understanding than traditional model. This proves that multiple representation has positive effects to concept understanding improvement. This strengthen findings of [7] that using different representations in learning can improve understanding and thinking about concepts, especially abstract concepts. The same thing was stated by [28], which is that it is very important to understand concepts through various types of representations, such as: verbal, pictorial and symbolic / mathematical, so that difficult concepts become easier to understand. The results of research by [29] found that multiple representation-based learning can improve concept understanding and problem-solving abilities. These results are also supported by the findings of [30,31], that multiple representation-based worksheets can improve self-
efficacy and physics problem solving abilities. Similar research results were also presented by [15] in his research that multiple representations application in quantum physics learning can improve concept mastery, science generic skill, and critical thinking skill. Students are able to interpret images into words and vice versa, to apply concepts in real life, to explain concepts, to compare and to infer. These are possible because multiple representations learning enables students to do activities including explaining, analyzing, relating, comparing, differentiating, and synthesizing [20]. Recognizing target concepts through analogy is able to help students improving abstract concept understanding [32,33] and able to eliminate misconceptions [34]. Analogy application in effective learning is able to improve students’ concept understanding and learning interests [35].

After recognizing target concept through analogy (first phase), students conduct experiment or observation and explain target concept verbally, visually, and symbolically. Explaining concepts with some ways can help students improving abstract concept understanding [36]. [7] further explain that learning with different representations can help students to improve their understanding and provide students alternatives to think about concept. Verbal explanation of a concept or problem will be easier to understand if it is followed by images and graphics. Texts and images are good representations to present problem contexts. Diagrams are suitable to present qualitative information, while graphics, formulas, numbers are best representing quantitative information [8].

Multiple representation is more effective in improving problem solving ability than traditional model. Statistical analysis shows significant difference postest of problem-solving ability between experiment and control groups (Table 5). Significant difference also occurs in normalized gain between experiment and control groups. Multiple representations-based learning can help improving students’ problem solving [14]. Explaining a problem with some ways (phase 2) is very good to present qualitative information before solving quantitative problem [8]. Different representations can be used to describe physics phenomena in some presentations to present complicated and abstract problems to be simpler and holistic so that students will be easier to understand [37]. In addition, [13] found that using different representations will be more successful in problem solving. Using only single representation will make problem solving very limited; for example, visual representation is very good for solving verbal problem only [38]. Physics problems, especially abstract and complex problems, involve images, visual, and complicated mathematics. Therefore verbal, pictorial, and symbolical representations are required to solve these problems.

Besides improving concept understanding, explaining concepts with different representations also helps students to solve problems. This problem solving contains three indicators: set up model, problem analysis, and verification. Statistical test results show that posttest indicators of problem solving are different significantly between experiment and control groups. In multiple representations-based learning, students are guided to apply concepts for problem solving by following solution examples. This will guide students to present both unknown and known components, to analyze problems, to write formulas to use, and to infer. Example of a problem similar to a problem to solve can help students to solve difficult and unfamiliar problem [39], [40] said similar notion that solution example with similar structure can help developing problem solving scheme.

4. Conclusion and Suggestion
Multiple representations can motivate students in learning activity, questioning actively, doing observation and interacting freely in looking information, and working individually and in groups. Based on statistic analysis independent sample t-test (Mann-Whitney) there was significance difference of normalization gain score between experimental and control groups on concept understanding and problem solving ability. Significant differences showed also in the posttest of concept understanding and problem solving between experimental and control group. This results showed that multiple representation learning had positive effects to concept understanding and problem solving abilities in electricity subject. Multiple representations was more effective in improving concept understanding and
problem solving abilities than traditional learning model that the lecturers have been using so far in electricity subject.

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