Profile of reasoning ability and reduction of mathematical anxiety in analogy-based physics learning

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Abstract. The analogy approach in learning physics encourages students to use logical reasoning in understanding physics concepts without anxious about mathematics. The purpose of this study were to analyze the reasoning abilities and the reduction of mathematics anxiety of students in analogy-based physics learning. This study used a mixed method design with an embedded experimental model by involving 72 students at senior high school. Quantitative data from the test were triangulated with qualitative data from questionnaires, observations, and psychological tests of mathematics anxiety. Based on data analysis, it was found that the ability to explore facts in questions, identify problems, apply physics concepts increased by an average of 41.66%, while making conclusions 22.50%. Meanwhile, based on the psychological scale analysis of anxiety which is divided into three clusters, the mathematics anxiety cluster on assignment (MAA), in the class (MAC), and for the student's future (M AF) has decreased by 21.76%, 32.87%, and 18.29% respectively. It can be concluded that the analogy-based physics learning significantly improve reasoning skills and reduce mathematical anxiety of students. Analogy-based learning encourages students to be able to solve physics problems by linking concepts with the peculiarities of phenomena which also have an impact on reducing their math anxiety.

1. Introduction

The purpose of learning is to provide opportunities for students to understand concepts and relationships between problems, solutions, or other representations [1]. In understanding concepts and solving physics problems, students need to have good reasoning skills. Reasoning abilities can affect problem-solving abilities, so it is very important for students to master [2]. Students who have high reasoning abilities can solve various problems even though they have undergone modifications in various forms [3].

One of the factors that greatly affects the performance of students in learning physics is mathematics anxiety [4]. High student math anxiety involves feeling tense and anxious which can affect the way students solve mathematical problems in real and academic life. Mathematics anxiety is a feeling of fear or a feeling of discomfort associated with numerical operations [5]. Not only are students involved in mathematics lessons in school academically, but any form of problems that involve numbers and calculations such as in physics, students will tend to feel tense and anxious.

There are three characteristics of people who have mathematics anxiety. The mathematics memorizer is someone who has memorized mathematical formulas but cannot apply these formulas to the concepts to be achieved. The second type is the mathematics avoider, someone who already has feelings of fear, anxiety, and tends to avoid math or math problems. The self-professed mathematics incompetent, someone who tends to feel that the field of mathematics is not a mastered field [6].
Analogy model is an alternative in studying the subjects of physics, mathematics, engineering, and other exact sciences [7]. This analogy learning model can be used to solve the confusion of learning communication between teachers and students, if students face learning difficulties in understanding new material but have a flow of thinking that is like previously taught material. Analogy is used as a tool in solving mathematics problems including mathematics anxiety. The more students practice using analogy, the analogy thinking process in student’s daily life will be formed and will have a good impact on learning outcomes and the development of other sciences [8].

Analogy is included in inductive reasoning, which is the process of reasoning a phenomenon against other similar phenomena [9]. Reasoning by analogy allows us to link distinct domains of knowledge and to transfer solutions from one domain to another [10]. Analogy is part of higher order thinking skills, so it is often associated with reasoning abilities. The reasoning that occurs is through a series of processes, namely students express their knowledge; students are faced with facts then look for similarities or do a similarity mapping; evaluation of the similarity mapping; draw conclusions and organize new information [11]. Therefore, this research has applied analogy-based physics learning as an effort to improve students' reasoning abilities as well as to reduce their mathematics anxiety.

2. Method

Mixed methods research with embedded experimental model was applied in this study to analyze the improvement of reasoning abilities and reduction of mathematics anxiety in analogy-based physics learning model as presented in Figure 1.

![Figure 1](image)

Figure 1. The mixed method used in the research

There were 72 students who were selected by purposive sampling to be involved in the research into two groups equally. Both groups were taught by using analogy-based learning model, but there were measured separately in terms of reasoning abilities (RA) for the first group and reduction of mathematics anxiety (MA) the second group. Their reasoning ability is measured using a test with four indicators, namely the ability to explore the facts contained in the questions; to identify problems; to apply physics concepts; and to draw conclusions. The data from the increase in reasoning ability were then analyzed by triangulation with data of observation, questionnaires, and psychological tests of mathematics anxiety. Aspects measured in observations and questionnaires include students' attitudes and interests towards analogy-based learning; as well as self-confidence in reasoning abilities and applying analogies in problem solving. The aspects measured in mathematics anxiety were anxiety during the learning process, anxiety when getting assignments, and anxiety facing the future with their inadequate mathematical abilities. Simple linear regression test to determine the effect of the implementation of analogy-based learning on students' reasoning abilities and students' mathematics anxiety. Paired sample t-test was employed to determine differences in students' reasoning abilities before and after being treated and N-gain calculation was used to analyze the reduction of mathematics anxiety.

3. Results and Discussion
There were a significant effect of analogy-based physics learning model in reasoning abilities of students as shown in Figure 2(a) – 2(c). The increase in reasoning ability can be seen from the answers of students before (pretest) and after (posttest) the implementation of analogy-based learning as in Figure 2. In the sample of pretest answer (2.a), student has not been able to explore the facts in writing. She count directly without writing down the facts that were known in the questions. She also still improperly identify the problem; immediately counted without identifying the problem; and have not been able to predict answers and apply physics concepts well. The pretest answer indicate that student have not yet reached the conclusion stage. Even though they have been able to answer the questions properly and correctly, students have not been able to draw conclusions from the answers that have been obtained.

![Figure 2. Student achievement in using reasoning abilities on problem solving](image)

a. Student’s performance in pretest, b and c student’s performances in posttest

However, after experiencing analogy-based learning, students' reasoning abilities improved significantly as presented in Figures 2.b and 2.c. The ability to identify problems is trained through analogy learning syntax, which is when looking for relevant concepts between the source concept and the target concept. Students are given the opportunity to identify things that are relevant between straight motion and circular motion, which can be done through identifying the meaning, physical quantities or through existing mathematical equations. This will help students when identifying the problems in the questions so that they are able to solve them in the right stages. This is in line with the results of research which show a correlation between reasoning abilities and student achievement [12]. In the simple linear regression test, the result shows that the significance value (Sig.) is 0.013 < 0.05, which means that there is an effect of the application of analogy-based physics learning on students' reasoning abilities. As for the average N-gain value of 0.83 which is included in the high criteria, which means that the application of analogy-based learning is effective in improving students' reasoning abilities. The application of analogy-based learning shows the potential to improve students' reasoning abilities due to the close relationship between analogy and reasoning [13].

From the aspect of reducing mathematics anxiety, the data also show a significant effect as shown in Table 1.

**Table 1. Calculation of N-gain for reduction of mathematical anxiety**
The table below shows the respondents' Mathematics Anxiety on assignments, Mathematics Anxiety in Class, and Mathematics for student’s futures:

| Responden (N) | Mathematics Anxiety on assignments (%) | Mathematics Anxiety in Class (%) | Mathematics for student’s futures (%) |
|---------------|----------------------------------------|---------------------------------|--------------------------------------|
| 36            | 21.76                                  | 32.87                           | 18.29                                |

From the simple linear regression test, it was obtained a significant result of, 0.00. This means that Ho is rejected and Ha is accepted, because the results are significant < 0.05, so it can be concluded that there is a significant difference in students' mathematics anxiety scores after taking analogy-based learning with those before analogy-based physics learning. Based on the results of the N-gain calculation, the effectiveness of student learning outcomes increases when analogy-based learning is carried out, reaching an increase of 0.59 with the criteria for moderate increase. This was in accordance with finding that learning physics by analogy can improve student learning outcomes [14] and there was a significant effect of learning by using an analogy approach to achievement, reasoning and learning independence of students[15]. The results of the application of analogy-based learning received a good response from students both from observation and questionnaires data. According to student’s opinion and performance, the analogy-based physics learning model could help them understand new concepts with similarities to the old concepts they were familiar with. This helps them improve their reasoning abilities and reduce their math anxiety in dealing with physics problems that contain mathematical operations.

4. Conclusion

Data from the test instrument corroborated through the triangulation process of observations and questionnaires as well as psychological tests on mathematics anxiety showed a significant increase in reasoning skills and a reduction in mathematics anxiety. The main key in analogizing the concepts that are already known by students into the concepts to be taught has helped students identify these concepts. However, not all physics concepts can be trained with an analogy-based learning model. But at least, these findings can be a further study to identify opportunities for applying this model to other physics concepts.

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