Effectiveness of problem solving-based module to improve analytical thinking

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Abstract. This research is the result of the effectiveness test of analytical thinking using the integration of problem solving and analytical thinking aspects in the human respiratory system material. The problem-solving aspects are identify, define, explore, act, and look back while the aspects of analytical thinking are differentiating, organizing, and attributing. The research method used was quasi-experimental. There were 74 participating students divided into two classes, namely the control class and the experimental class. The effectiveness of the analytical thinking process is based on two types of questions, namely multiple-choice and metacognitive questions. The results show that 1) the average score of the analytical thinking process using multiple-choice questions of the experimental class (76.95) is higher than that of the control class (65.20); 2) the average score of the analytical thinking process using multiple-choice questions of the experimental class (61.72) is higher than that of the control class (60.63); and 3) the average score of aspects of the analytical thinking process of the experimental class is higher than that of the control class, but the students obtain the lowest score in the organizing aspect.

1. Introduction

One higher order thinking skill needed to face competition in the 21\textsuperscript{st} century is problem solving [1–3]. Problem solving is one of the ways of thinking that has the aspects of: Identifying and Defining the problem, Exploring strategies, Acting on the strategies, Looking back and evaluating the effects of your activities [4]. It includes a series of efforts needed to find effective, logical, and systematic solutions to solve problems [5,6].

Problem solving is important in the learning process because it supports the development of skills in the 21\textsuperscript{st} century [7–10]. Problem solving used in the learning process helps students solve problems that require higher order thinking processes [11]. The learning process that uses problem solving can help students improve analytical thinking [12,13].

Analytical thinking is the activities of examining and breaking down information into smaller parts by identifying causes, making conclusions, and finding evidence to support generalizations [14]. Analytical thinking is a thinking process to classify the elements of something into several parts to determine where the elements are made from and how they are interconnected. Analytical thinking has three aspects of differentiating, organizing and attributing [15]. The analytical-thinking aspects are needed to solve the problem through problem identification and further investigation[13].

Analytical thinking developed through problem solving uses a series of activities that include investigating, searching for truth, developing ideas, and making decisions to solve problems [16,17].
Problem solving that accommodates the improvement of analytical thinking in the learning process can be trained through one of the references, namely modules [17–19].

A module is a collection of materials that contains various information about the learning content that is taught in the learning process [20,21]. It plays an important role in the learning process because it can improve the effectiveness of learning and the quality of education [20]. Learning with modules has been renewed along with the progress of the times [22]. It should be able to encourage higher order thinking skills [23], one of which is the aspect of problem solving.

Problem solving-based modules can facilitate students to learn independently and solve problems by doing analysis in each activity [13]. Activities, objectives, materials, and questions in problem solving-based modules are in accordance with the indicators based on problem-solving aspect, as to research of [24] that uses problem-solving activities to learn mathematical concepts and skills. The problem-solving aspects in the module are visualized into each activity that involves students to be active in the learning process [10,25]. The research of [26] states that the aspects of problem solving can improve students' critical thinking. [27] also mention that the ICAE learning model positively influences students' analytical thinking, so the aspects of problem solving are used to determine the increase in students' analytical thinking. The problem-solving aspects in the module are oriented towards improving analytical thinking which is very important for the success of students in the future [28]. Modules based on problem-solving aspects contain activities that group materials into smaller parts, determine the relationship between each part and the overall structure, and determine the purpose of the information conveyed in accordance with analytical thinking [29]. Modules based on problem-solving aspects become a powerful tool to support the improvement of analytical thinking [13], so it is necessary to measure the improvements in analytical thinking through problem solving-based modules.

2. Research Method
The research design was a quasi-experimental setting with pretest-posttest nonequivalent control group design using two classes, namely the control class and the experimental class. This research was conducted at class XI Science of SMA N Karangpandan with 147 students of the samples divided into 4 classes. The samples were selected cluster random sampling resulting class XI Science 2 as the control class and XI Science 1 as the experimental class with a total of 37 students of each class. The control class and the experimental class used the same lesson plan, media, facilities, infrastructure, and teacher. The control class used the modules that are used in schools while the experimental class used the problem solving-based modules which had previously been arranged based on 120 indicators that were made from the aspects of problem solving and analytical thinking. The control class and the experimental class worked on the pretest questions, got treatment according to the test design (Table 1), and worked on the posttest questions.

Pretest-posttest consist of two types of questions, namely multiple-choice questions and metacognitive questions used as the research data. The pretest-posttest scores of the multiple-choice questions are calculated by dividing the correct numbers with the number of questions which is then multiplied by 100. For the pretest-posttest scores of the metacognitive questions, they are calculated by three times the combined scores (cognitive score plus the score based on metacognitive assessment rubric) minus cognitive score, and then the result is divided by 2. The scores based on the metacognitive assessment rubric by Kristiani et. al [30]. The data analysis technique used the Ancova test with the SPSS version 22 application with a significance level of 0.05.
Table 1. Pretest-posttest non-equivalent control group design

| Class      | Pretest | Treatment | Posttest |
|------------|---------|-----------|----------|
| Control    | O₁      | X₁        | O₂       |
| Experimental | O₃      | X₂        | O₄       |

O₁ : Pretest given to the control group
O₂ : Posttest given to the control group
O₃ : Pretest given to the experimental group
O₄ : Posttest given to the experimental group
X₁ : The control group uses modules from the school
X₂ : The experimental group uses modules based on the integration of problem-solving and analytical-thinking aspects

3. Result and Discussion

3.1 Result

The results of the effectiveness of analytical thinking based on problem solving-based modules were analyzed using the Ancova test on multiple-choice and metacognitive question data. The Ancova test was preceded by parametric prerequisite tests, namely the normality test using Kolmogorov Smirnov and homogeneity test using Levene's test. Normality and homogeneity tests showed the pretest-posttest data of multiple-choice and metacognitive questions in the control and experimental classes are normally distributed and homogeneous because of the Sig. value is > 0.05, so that a verification test was performed which included the correlation test and the interaction test. Correlation test was used to determine whether there is a relationship between the pretest and posttest scores on multiple-choice and metacognitive questions. Correlation test resulted in Sig. value of < 0.05, which means that there is a strong correlation between the pretest and posttest scores on multiple-choice and metacognitive questions in terms of Pearson's correlation value of 0.630. Interaction test was used to find out the interaction between the pretest and class on the multiple-choice and metacognitive questions. It used multiple-choice and metacognitive test data that yield the Sig. value of > 0.05, which means there is no interaction between pretest and class variables. The results of the correlation and interaction tests met the requirements to proceed to the Ancova test stage which was used to determine differences in the scores of analytical-thinking posttests of the control and experimental classes on multiple-choice and metacognitive question data. The results of the Ancova test for multiple-choice and metacognitive test data are shown in Tables 2 and 3.

Table 2. The results of the effectiveness of analytical thinking based on problem solving-based modules using the multiple-choice type of questions

| Class      | Average pretest | Average posttest | F       | Significance value (Sig.) | Partial Eta Squared |
|------------|-----------------|------------------|---------|---------------------------|---------------------|
| Control    | 39.39           | 65.20            | 1137.49 | 0.000 (<0.05)              | 0.941               |
| Experimental | 38.10           | 76.95            |         |                           | (estimated parameter 13.16) |

Table 2 shows the average posttest score of the analytical thinking test using the multiple-choice type of questions in the experimental class (using problem solving-based modules) of 76.95 > 65.20, which is higher than the score of the control class (using modules used at school). A significant difference in the results of the control class and the experimental class using multiple-choice questions is indicated by the significance result of 0.000 (< 0.05). The estimated parameter value of multiple-choice questions is 13.16, which means that the class using problem solving-based modules gets a score of 13.16 higher than that of the class that use school modules. Problem solving-based modules provide an effective contribution to increasing the score of analytical thinking by 94.1% based on the results of Partial Eta Squared using multiple-choice questions.
Table 3. The results of the effectiveness of analytical thinking based on problem solving-based modules using the metacognitive type of questions

| Class     | Average pretest | Average posttest | F       | Significance value (Sig.) | Partial Eta Squared |
|-----------|-----------------|------------------|---------|---------------------------|---------------------|
| Control   | 34.06           | 60.63            | 30.70   | 0.000(<0.05)              | 0.302               |
| Experimental | 34.82           | 61.72            |         |                           |                     |

Table 3 shows the average posttest score of the analytical thinking test using the metacognitive type of questions in the experimental class (using problem solving-based modules) of 61.72 > 60.63, which is higher than the score of the control class (using modules used at school). The significant differences of the results between the control class and the experimental class using metacognitive questions are shown with a significance result of 0.000 (< 0.05). The estimated parameter value of metacognitive questions is 0.68, which means that the class that uses the problem-solving based module gets a score of 0.68 higher than the class that uses the school module. Problem solving-based modules provide an effective contribution to increasing the score of analytical thinking by 30.2% based on the results of Partial Eta Squared using metacognitive questions.

The average scores of analytical thinking between the control class and the treatment class based on multiple-choice and metacognitive questions represent the scores of differentiating, organizing, and attributing aspects as shown in Table 4.

Table 4. The scores of analytical thinking aspects on multiple-choice and metacognitive types of questions

| Variabel               | Control Class | Experimental Class |
|------------------------|---------------|--------------------|
|                        | Pretest       | Posttest           | Pretest       | Posttest |
| Multiple-choice questions |               |                    |               |         |
| Differentiating        | 13.31         | 21.41              | 12.97         | 25.74   |
| Organizing             | 10.81         | 19.26              | 9.72          | 22.43   |
| Attributing            | 15.27         | 24.52              | 15.4          | 28.7    |
| Metacognitive questions |               |                    |               |         |
| Differentiating        | 11.29         | 20.56              | 11.4          | 25.51   |
| Organizing             | 9.75          | 17.9               | 10.12         | 24.12   |
| Attributing            | 13.01         | 22.16              | 13.29         | 27.59   |

Table 4 shows the score of each aspect of analytical thinking on multiple-choice and metacognitive types of questions including differentiating, organizing, and attributing that experience an increase. The average scores of all aspects of analytical thinking have increased, but the score of organizing is the lowest in the control and experimental classes.

3.2 Discussion

The use of modules based on problem-solving aspects has a positive effect on improving students' analytical thinking on multiple-choice questions and metacognitive questions. The highest increase is in the attributing aspect while the lowest is in the organizing.

Attributing is the activity of determining the main problem to solve the problem [31]. Good attributing affects the ability of students to determine problems [32], define problems [33], find appropriate solutions [34,35], solve problems with selected solutions [36], and evaluate the results of problem solving [24] that are an important part of life in the future. Low attributing affects the ability of students to determine the intent of the problem and the selection of strategies, so that the strategy chosen is not appropriate to solve the problem [37]. The way to increase the attributing score is by re-attributing training to students in learning through feedback activities [38] using problem solving-based modules. The attributing scores in the two research classes are the highest compared to the differentiating and organizing scores. The attributing score in the class that uses the problem solving-
based module shows that problem solving directs students to determine the goals of the problem being solved in accordance with the objectives of attributing.

Organizing is the activity of identifying the elements of a communication or event and recognizing that they mutually support one another to create a logical structure [39]. Good organizing can increase students' ability to recognize problems [40], link knowledge with solutions to solve problems [33], connect ideas and find the right solution to solve problems [41]; determine the effect of the chosen solution to the problem [42] and, determine the relationship between the results of problem solving and the effectiveness of the solution used [43]. Weak organizing causes errors in the selection of solutions to solve problems [44] that have an impact on problems that cannot be solved [45]. The way to increase the score of organizing is to practice deep understanding of content through activities in the module [19]. The scores of organizing in the two research classes increase due to the use of problem solving-based module, but it is the lowest increase. The increase in the low score of organizing is caused by errors in recognizing problems, choosing inappropriate solutions, and lack of knowledge to connect ideas that are not in accordance with the objectives of organizing [14].

The increased scores of identifying, organizing, and attributing using multiple-choice and metacognitive types of question are due to the problem solving-based module that is used according to student characteristics. Multiple-choice and metacognitive questions represent analytical thinking that trains students to control their own learning processes that are appropriate to their needs to live in the 21st century [46].

Effective problem solving-based modules improve analytical thinking based on the multiple-choice type of questions because they can influence the way of viewing a problem and how to solve it. Analytical thinking is increased based on the type of metacognitive questions because problem solving-based modules can affect students' awareness and regulation of their knowledge about the problem to be solved and how to manage that awareness to get the right solution in solving problems [47]. [48] prove that good metacognition skills can support 90% of the student's academic success, so metacognitive questions in problem-based modules are important to use to improve analytical thinking.

Research [27] shows that learning using learning models significantly improves analytical thinking. The problem solving-based module can facilitate students to gain knowledge during the learning process because it contains learning activities that encourage students to analyze a problem and how to solve it [16], so that their analytical thinking increases. Increased analytical thinking shows that the students have the knowledge that can be used to solve problems in a planned, independent, and complete manners. Having high analytical thinking has a positive effect on the student's achievement of learning objectives in accordance with the expected curriculum [49,50].

4. Conclusion

Learning using a problem solving-based module is effective in improving students' analytical thinking as evidenced by the Ancova test on multiple-choice and metacognitive types of questions. Problem-solving aspects which include Identifying the problem, Defining and representing the problem, Exploring possible strategies, Acting on the strategies, Looking back and evaluating the effect of your activities are a structural unit that can build students' abilities for differentiating, organizing, and attributing. Improved analytical thinking has a positive effect on students' knowledge that can be used to solve problems appropriately. Analytical thinking and problem solving can be used as an alternative to further the research, namely the application of the topic other than the human respiratory system. Alternatively, the future researchers can integrate analytical thinking with other skills in the human respiratory system topic.

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