

The Effect of Concept Map Learning Model on Student's Reasoning

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Abstract *Purpose:* This study aims at investigating the effectiveness of the concept map learning model on student reasoning. *Methodology:* It is an experimental study with the students of Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Muhammadiyah Surakarta in 2017/2018 academic year as the population with a total of 35 students of IVB semester as the respondents. The data collection techniques included tests and documentation. *Results:* The results of the Mann-Whitney Test showed a p-value of $0.012 < \alpha = 5\%$, hence H_0 was rejected, which implied that the scores of the post-test of the two classes were different at the 5% level of significance. It indicates a significant difference in reasoning skills. *Applications/Originality/Value:* Based on the average values of the two classes, an increase in the reasoning of students in the experimental class is higher than those in control. Thus, it can be concluded that the implementation of models and tools of concept maps in the Introduction to Real Analysis has been effective in improving student reasoning.

Keywords Learning Model, Real Analysis, Concept Map, Experimental Design

1. Introduction

Introduction to Real Analysis is one of the compulsory subjects that must be enrolled by the students of Mathematics Education, Faculty of Teacher Training and

Education, Universitas Muhammadiyah Surakarta. Bartle and Sherbert (2010) claimed real analysis as the body of mathematics. It is the theoretical basis of Differential Calculus and Integral Calculus, in which both of these subjects are extensively applied to assorted fields of life. Introduction to Real Analysis discusses the principles, rules, traits, and proofs of the basic concepts that build the structure of mathematical sciences. The materials include the properties of algebraic, sequences, and completeness of the real number; Rows of real numbers that include convergent, limited, monotonous, and Cauchy sequences; Limit function; and continuity, discontinuity, and uniform continuity of a function.

In studying the Introduction to Real Analysis, students are required to comprehend the definition, characteristics, criteria, and proofs of each concept. Besides, they are also required to understand the interrelationships between concepts due to the significance of the relationship between the concepts. Experience and observations of the learning activities indicate that several problems should be resolved immediately. First, Introduction to Real Analysis is a pure mathematics course that discusses the definitions, traits, and proofs of the truth of all basic concepts, both abstract and symbolic. Due to its abstract and symbolic properties, the learning process is inclined to be textual with lecturer-centered methods, hence students are passive and they face difficulties in correlating concepts of real analysis. Secondly, in studying the Introduction to Real Analysis, students are required to possess logical and systematic thinking skills. They must be able to understand the concepts in terms of definitions, properties, criteria, or

evidence of truth in the concept, and to link the concepts that have been previously discussed to build new concepts.

However, several studies showed that most of the students demonstrate the difficulties to understand the subjects in Real Analysis. Widiati and Stephani (2018) revealed that, in learning Real Analysis, the students' have several difficulties: determine the initial idea of the proof process, think critically, logically, creatively, reasoning, and systematic, and express the ideas into non-verbal language. Sari, Waluyo, Ainur, and Darmaningsih (2018) investigated the student's logical errors in proving a theorem in the Real analysis course. They revealed that the students seem confused in using definitions of cluster point, the limit of a function, and limit of sequences. The difficulties of proof also have been investigated by Maslahah, Abadi, and Ibrahim (2019). They stated that the difficulty in proving was constructing and understanding the proof, and evaluating the mathematical proof. The lack of prior and relevant knowledge in the use of theorems and notations was caused of these difficulties. Besides, Azrou and Khelladi (2019) also investigated that the lack ability of undergraduate students in proving was caused by the lack of meta-knowledge about proof, and weak mastery of concepts was identified.

Proof ability and reasoning can't be separated. Both have been considered as two sides of the coin. Ball and Bass (2003) state reasoning is a basic mathematical skill required for understanding mathematical concepts, applying mathematical ideas and procedures, and constructing mathematical understanding. Besides, the reasoning is the cognitive process to draw the conclusions based on the principles, rules, nature, or existing evidence (Sternberg, 2009). Brodie (2010) asserts that reasoning is very essential in mathematics. It is a tool to understand, relate, and build the structure of mathematical knowledge. Moreover, Mueller and Maher (2009) state students' mathematical understanding depends on reasoning. Therefore, the reasoning is important in growing mathematical knowledge. Through mathematical reasoning abilities, students can overcome unfamiliar situations that form the foundation of other material (Battista, 2016). Furthermore, NCTM (2000) suggests reasoning is drawing conclusions of proofs, grounds, or assumptions that involve developing logical arguments to deduce or infer conclusions. In other words, reasoning is an effort to conclude by using logical rules based on assumptions, principles, properties, and pre-existing proofs. It argues that reasoning entails an understanding of logical rules and how to relate former concepts, rules, principles, properties, or proofs to formulate or draw a conclusion or new evidence.

In the introduction to real analysis, knowledge structures are constructed in the form of a network that correlates one concept to others. No single concept is truly single or isolated. By using concept maps, it will be easier to understand such knowledge structure as well as to build new mathematical knowledge structures. Concept maps are

structural taxonomies and can be categorized into 3 types, namely, chain, spoke, and net (Kinchin, Hay, & Adams, 2000). The concept map developed by Novak and Govin (1984) is a strategy to build knowledge structures to reveal the relation among concepts in a topic. The National Center on Accessing the General Curriculum (NCAGC) states 8 effective enhancements in learning, one of which is the concept map (Little, 2009). In its development, concept maps are broadly used to build new concepts based on the concepts that have been previously studied.

Brinkman (2005) proposes several benefits of concept maps as derived from experiences in applying concept maps, namely: to organize information on a topic easily, facilitate meaningful learning, organize and understand new learning material, to identify student knowledge structures, to easily memorize and recall the structures of concept maps since they are in a unity of graphics and images, and to revise a topic. The ability of students to design concept maps can illustrate students' conceptual understanding. Weak conceptual understanding has an impact on the lack of students' ability to prove mathematics (Varghese, 2009). Safdar, Hussain, Shah, and Rifat (2012) suggest that learning with concept maps can improve both cognitive skills and affective skills of students. It implies the meaningfulness of concept maps to develop students' capacity.

Studies in applying concept maps to enhance students' reasoning ability have been carried out (Ayal, Kusuma, Subandar, & Dahlan, 2016; Khotimah, Masduki, & Sungkono, 2019). Ayal et al. (2016) have promoted mathematical reasoning ability for junior high school students. On the other hand, Khotimah et al. (2019) have implemented the concept map to enhance undergraduate students' reasoning ability in solving real number system, a part of subjects in real analysis course. However, the research by Khotimah et al. (2019) is limited to one-group design. Although the results of the study showed an increase in reasoning ability; however, the design used can't guarantee that the concept map is a factor that determines the increase of the reasoning ability. The present study will extend the results of previous studies using experimental designs with control and experimental classes. This design is used to ensure that the concept map is a determinant factor to increase the students' reasoning ability. Thus, the objective of this study is to examine the effectiveness of concept map models to improve the students' reasoning ability in Real Analysis course. This study will propose the innovative learning models on the Real Analysis course which is one of the difficult subjects for most mathematics undergraduate students.

2. Research Method

The present study is a research and development project. (Sugiyono, 2009) claims that research and development is

a method used to create and test the effectiveness of a product. This study consisted of two stages and was carried out in two years. The respondents were the 4th-semester students of Mathematics Education Study Program, Universitas Muhammadiyah Surakarta, who were enrolled in the Introduction to Real Analysis course.

The first year of this study is the development stage which aims at developing learning models and tools for Introduction to Real Analysis based on concept maps. It begins with a literature study and topic analysis of Introduction to Real Analysis to devise learning tools. It is followed by designing the model and learning tools, i.e., Lesson Plans, teaching materials, Student Worksheets, mathematical reasoning assessment instruments, and instruments for research data collection, which include model validation instruments, learning activities observation, feasibility questionnaire, and model implementation. The results of the learning model and tools are then discussed with and validated by the learning experts. Subsequently, a limited model trial in the class is conducted to determine the implementation of the learning model and tools by using action research methods. The second-year is the implementation stage of the learning model and tools in the classroom. The outcome of reflection and evaluation of the limited trial in the first year becomes the basis for revision to be implemented on a broader scale. In this second year, the learning model and tools are implemented in Universitas Muhammadiyah Surakarta (UMS) and also tested by partners of UMS.

Data collection techniques are tests, observation, and documentation. Tests are used to collect data on students' reasoning, observations are used to observe the implementation of models and learning tools based on concept maps in classroom, and documentation is used to document the entire process and results of research. The data were processed by using SPSS and analyzed by using non-parametric inferential. The N-gain score was used to

analyze the effectiveness of the models.

3. Results and Discussion

In the second year, a revised concept map-based learning tools which included a Weekly Lesson Plan (RPM), student worksheets (LKM), teaching materials, assessment instruments, and observation sheets for lecturers and student activities were produced. Weekly Lesson Plan is compiled to achieve learning outcomes: proving the properties in the real number system \mathbb{R} with learning indicators: explaining the properties of the sequence of \mathbb{R} , proving the properties derived from the sequence in \mathbb{R} , applying the properties of sequence to discontinuity in \mathbb{R} , explaining the upper and lower limits of the set, explaining the supremum and infimum of a set, determining the supremum and infimum of a set, explaining the completeness of \mathbb{R} , and proving the properties of supremum and infimum of a set. Weekly Lesson Plan is also compiled to achieve learning outcomes: proving the properties of the real numbers, with the formulation of learning indicators: explaining the meaning of convergent and limited sequences, proving the theorem of row limit, and proving the properties of convergent sequences.

The present study was conducted in two different classes as samples that were randomly selected using cluster random sampling technique. The IVB class consisting of 35 students became the experimental class with the intervention of a concept map learning model, while the IVA class consisting of 35 students became a control class subjected to the conventional learning model. Before the intervention, these two classes were exposed to a pre-test and a balance test was carried out to find out the initial skills of students in these two classes. The results of the balance test were examined using SPSS is presented in Table 1 below.

Table 1. The result of the balance test by Mann-Whitney Test

| | | Ranks | | |
|--------------------------------------|--------------|----------|-----------|--------------|
| Experimental class and Control class | | N | Mean Rank | Sum of Ranks |
| Pre-test score | Experimental | 35 | 35.17 | 1231.00 |
| | Control | 35 | 35.83 | 1254.00 |
| | Total | 70 | | |
| Statistics Test ^a | | | | |
| Pre-test score | | | | |
| Mann-Whitney U | | 601.000 | | |
| Wilcoxon W | | 1231.000 | | |
| Z | | -.138 | | |
| Asymp. Sig. (2-tailed) | | .890 | | |

a. Grouping Variable: Experimental class and control class

H₀: Both populations are identical (the pre-test scores of the two classes are insignificantly different).

H₁: Both populations are not identical (the pre-test scores of the two classes are significantly different).

Decision-making:

If the asymp value is sig (2 tailed) $> \alpha = 5\%$, then H_0 is accepted.

If the asymp value is sig (2 tailed) $< \alpha = 5\%$, then H_0 is rejected

Test Conclusion:

The value of asymp value (2 tailed) proved the p-value. The p-value obtained is $0.890 > \alpha = 5\%$, then H_0 is accepted which means that the pre-test scores of the two classes are identical (insignificantly different) at the 5% level. It indicates the initial ability of both classes is balanced.

After being claimed balanced, the implementation of the model and learning tools of concept maps was carried out in the experimental class, while the conventional learning model was applied in the control class. In the experimental class, the revised learning model and tools were implemented on Tuesday, 27 February 2018, with the goals: after reviewing the material and group discussion, students are expected to be able to explain the properties of the sequence in \mathbb{R} , prove the properties derived from the sequence in \mathbb{R} , and apply the properties of sequence in a discontinuity in \mathbb{R} . The core activity was initiated with the presentation of the material of sequence by the lecturer. Furthermore, the lecture facilitated the students to form groups consisting of 3-4 students. Each group was equipped with a Student Worksheet (LKM) about the properties of the sequence in \mathbb{R} . Students discussed and explored the topic from various learning sources. Learning resources could be obtained from the previous presentation of lecturer, student worksheets (LKM), or textbooks. Subsequently, the lecture facilitated each member of the discussion group to identify the most common concepts on the topic as main ideas. In addition to identifying the main ideas, they also discussed additional ideas or specific concepts, which support the main ideas. They arranged main ideas and additional ideas into a chart, by putting the most common main ideas on the top and adding additional ideas under the main ideas. They also provided connecting labels between main ideas and additional ideas. After determining a more specific concept in the second row, students continued to determine other more specific concepts in the third row, provide a connecting label, and so on so until a concept map was formed. Through these concept maps, students' visual representations regarding mathematical concepts can be seen (Lapp, Nyman, & Berry,

2010). Students verified concept maps that had been prepared by presenting the results of the produced concept map. Other groups responded to the results of the group presentation and the lecturer confirmed the correct answers.

The second section took place on Tuesday, 13 March 2018, with the goals: after reviewing the material and group discussions, students were expected to be able to explain the upper and lower limits of the set, explain the supremum and infimum of a set, determine the supremum and infimum of a set, explain the completeness, and prove the properties of and infimum of a set. Meanwhile, the third section was held on Tuesday, 27 March 2018 with the aims: after reviewing the material and group discussions, students are expected to be able to explain the definition of the limited row, prove the theorem of the limit row, and prove the properties of convergent row.

At the end of the lesson, a post-test was given to both the experimental class and control class to test the effectiveness of the developed model and the learning tools. The results of the normality test with Kolmogorov Smirnov SPSS indicated that the samples did not originate from a population that was normally distributed. The test of normality of pre-test data and post-test data are presented in Table 2 and Table 3, respectively.

The Output of Test of Normality:

This section will test the normality of the distribution of data.

Decision Making:

Sig value. (in the Kolmogorov-Smirnov test) or significance or probability value < 0.05 , the distribution is not normal.

Sig value. (in the Kolmogorov-Smirnov test) or significance or probability > 0.05 , the distribution is normal.

Test of Normality Analysis:

The results of the Kolmogorov Smirnov test with SPSS are as follows:

The pre-test data of the experimental class was the probability value (Sig.) = 0.000, while the control class was probability value (Sig.) = 0.006. The probability value is below 0.05 ($p < 0.05$), then the data was not normally distributed.

Table 2. The Test of Normality of Pre-test Data

| | Experimental class and control class | Kolmogorov-Smirnov ^a | | | Shapiro-Wilk | | |
|----------------|--------------------------------------|---------------------------------|----|------|--------------|----|------|
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| Pre-test score | Experimental | .237 | 35 | .000 | .910 | 35 | .007 |
| | Control | .179 | 35 | .006 | .912 | 35 | .009 |

a. Lilliefors Significance Correction

Table 3. The Test of Normality of Post-test Data

| | Experimental class and control class | Kolmogorov-Smirnov ^a | | | Shapiro-Wilk | | |
|-----------------|--------------------------------------|---------------------------------|----|-------------------|--------------|----|------|
| | | Statistic | df | Sig. | Statistic | Df | Sig. |
| Post-test score | Experimental | .101 | 35 | .200 [*] | .959 | 35 | .208 |
| | Control | .176 | 35 | .008 | .912 | 35 | .008 |

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The Output of Test of Normality:

This section will test whether the data distribution is normal or not.

Decision Making:

Sig value. (in the Kolmogorov-Smirnov test) or significance or probability value < 0.05, the distribution is not normal.

Sig value. (in the Kolmogorov-Smirnov test) or significance or probability value > 0.05, the distribution is normal.

Test of Normality Analysis:

The results in the Kolmogorov Smirnov test with SPSS are as follows:

The post-test data of the experimental class was the probability value (Sig.) = 0.200, while for the control class was the probability value (Sig.) = 0.008. The probability value of the experimental class was above 0.05 (p > 0.05), then the data was normally distributed. While the probability value of the control class was below 0.05 (p < 0.05), then the data was not normally distributed.

Test of Significance

Since the test of normality was not fulfilled, the data were analyzed using non-parametric tests. The results of the non-parametric test using the Mann-Whitney Test are presented in Table 4 as follows.

Table 4. The Output of the Non-Parametric test by Mann-Whitney Test

| Ranks | | | | |
|--------------------------------------|----------|-----------|--------------|--|
| Experimental class and control class | N | Mean Rank | Sum of Ranks | |
| Experimental | 35 | 41.61 | 1456.50 | |
| Post-test Control | 35 | 29.39 | 1028.50 | |
| Total | 70 | | | |
| Statistics ^a | | | | |
| Post-test score | | | | |
| Mann-Whitney U | 398.500 | | | |
| Wilcoxon W | 1028.500 | | | |
| Z | -2.515 | | | |
| Asymp. Sig. (2-tailed) | .012 | | | |

a. Grouping Variable:
Experimental class and control class

H₀: The two populations are identical (the Post-test scores of the two classes are insignificantly different).

H₁: The two populations are not identical (the Post-test scores of the two classes are significantly different).

Decision Making:

If the asymp value is sig (2 tailed) > α = 5%, H₀ is accepted.

If the asymp value is sig (2 tailed) < α = 5%, H₀ is rejected.

Test Conclusion:

The value of asymp sig (2 tailed) indicates p-value. The obtained p-value was 0.012 < α = 5%, hence H₀ was rejected implying the post-test scores of experimental class and control class were not identical or different at the 5% level. It shows that there is a significant difference in reasoning skills between those classes.

Test of Effectiveness

The effectiveness of the implementation of the concept map in learning was examined using the Mann-Whitney Test based on the N-gain score of the experimental and control class. The results of the Mann-Whitney test is presented in Table 5 as follows:

Table 5. The Output of the Mann-Whitney Test of the N-gain Score

| Ranks | | | | |
|--------------------------------------|----------|-----------|--------------|--|
| Experimental class and control class | N | Mean Rank | Sum of Ranks | |
| Experimental | 35 | 41.53 | 1453.50 | |
| Post-test Control | 35 | 29.47 | 1031.50 | |
| Total | 70 | | | |
| Statistics ^a | | | | |
| Post-test score | | | | |
| Mann-Whitney U | 401.500 | | | |
| Wilcoxon W | 1031.500 | | | |
| Z | -2.479 | | | |
| Asymp. Sig. (2-tailed) | .013 | | | |

a. Grouping Variable:
Experimental class and control class

H₀: There are no significantly different in the effectiveness of the two classes.

H₁: There are significantly different in the effectiveness of the two classes.

Decision Making:

If the asymp value is sig (2 tailed) > α = 5%, H₀ is accepted.

If the asymp value is sig (2 tailed) $< \alpha = 5\%$, H_0 is rejected.

Test Conclusion:

The obtained p-value was $0.013 < \alpha = 5\%$, hence H_0 was rejected. Thus, it can be concluded that the experimental class by implementing the concept map in learning is more effective than the control class which was carried out by the traditional method.

By the results, the average scores of the pre-test and post-test of the control class were 52.43 and 52.63, respectively. It means that the reasoning of students in the control class has increased by .20. Meanwhile, the average scores of pre-test and post-test of the experimental class were 44.2 and 62.34, respectively. It indicates there is an increase of 18.14. Besides, the average N-Gain score of experimental and control class are 0.28 and -0.46, respectively. Therefore, it can be concluded that although the average score of pre-test and post-test of the experimental class is increased, the effectiveness of the implementation of the model is still low. However, the experimental class shows more effective than the control class to enhance the students' reasoning ability. In other words, the implementation of learning models and tools based on concept maps in the Introduction of Real Analysis has improved students' reasoning.

The results of this study confirm the results of a study carried out by Serhan, Syam, and Aimdallal (2014), in which concept maps help students to have a deeper understanding of the concept of Euler Circuit and to construct various representations of this concept. The results of this present study also supported by Chen, Lin, and Nien (2014) and Karakuyu (2010) about the effectiveness of concept maps as a tool to improve the meaningfulness of learning and understanding concepts. Similarly, it reasserts Safdar et al. (2012) on the use of concept maps in physics learning to improve science skills and more meaningful learning. Furthermore, Chiou (2008) concludes that the implementation of concept maps in learning improves the students' understanding of concepts and interests. The same results have been disclosed by Asan (2017), Orue, Alvarez, and Montoya (2008), Brown (2009), and Chang, Yeh, and Shih (2016).

The research conducted by Bot and Eze (2016) concluded that trigonometric learning with concept maps is better than cooperative learning, while both of these learning is better than conventional learning. Therefore, the idea of a combination of concept maps and cooperative learning is appropriate for mathematics learning. Besides, concept maps are a medium to stimulate high-level thinking so that students' abilities could be increased (Ghani, Yahaya, Ibrahim, Hasan, & Surif, 2017).

4. Conclusion

The present study reveals there is a significant difference

in student reasoning ability. Based on the average scores of the experimental and control class, an increase in student reasoning after the implementation of the concept maps-based learning model and tools has been more obvious than those in the control class. The effectiveness of the models also showed on the average N-gain score. Thus, it can be concluded that the implementation of models and tools of concept maps in the Real Analysis course is effective for improving students' reasoning ability.

The innovative learning to teach Real Analysis, one of the difficult subjects of most students, is still a challenge, especially to improve the high-order thinking skills (HOTS) of the students. This skill is very useful for students to be able to compete and survive in the current era of disruption. The learning model based on concept maps is one of the innovative learning models proposed. However, the low effectiveness of the models, with average N-gain score 0.28, needs to be improved. Thus, the longer implementation in learning is expected to increase the effectiveness of the model.

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