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Bruner's Cognitive Stages and Their Effects on the Understanding of Fraction Concept

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Abstract

This study aimed at determining: (1) the difference in the effect of employing the Bruner's cognitive stages on the students' understanding of fractions concept, (2) which of the Bruner's cognitive stages gave better effect on the students' understanding of the fractions concept, and (3) the linkage of Bruner's cognitive stages which gave the best effect on the students' understanding of fractions concept based on the students' self-efficacy. This research was a mixed method of the explanatory sequential type that combined quantitative and qualitative research. At first, experimental research was conducted then a case study was conducted to complement quantitative data. The population of this study was students of grade VII of SMP Negeri 2 Semarapura consisted of nine classes and the samples were three classes chosen with random sampling technique. The data of students' understanding of fractions concept were collected through the test and students' self-efficacy data were collected using questionnaires, observation, and interviews. Quantitative research data were analyzed by Analysis of Variance (ANOVA), and qualitative data were analyzed descriptively. The results show that (1) there are the different influence of Bruner's cognitive stages on students' understanding of the fractions concept. (2) learning fractions through Bruner's cognitive stages with the order "enactive, iconic, symbolic" has the highest impact on the students' understanding of the concept, (3) the students' self-efficacy on learning through Bruner's cognitive stages with the order " enactive, iconic, symbolic" has a positive relationship with the understanding of the fractions concept, where students with high self-efficacy tend to have high understanding of the fractions concept while students with low self-efficacy tend to have low understanding of the fractions concept.

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1. Introduction

One of the essences of mathematics is the queen and the maid of science. This suggests that mathematics has an important role in improving the quality of education so that the mastery of strong mathematics is required early (Suherman *et al.,* 2003). In general, students' mathematics learning outcomes had not been in line with the expectations.

The Program for International Student Assessment (PISA) conducted a study of students who were 15 years old (junior high school students). One of the studies related to mathematical literacy. The results of PISA 2009, Indonesia was ranked 61 out of 65 participating countries with an average score of 371, while the international average score was 496 (OECD, 2009). In PISA 2012 Indonesia was ranked 64 out of 65 participating countries with an average score of 375, while the international average was 494 (OECD, 2012) and in 2015 Indonesia was ranked 67 out of 72 participating countries with an average score of 386, while the international average was 490 (OECD, 2016). The low results of PISA could be used as a reflection of all parties to improve the quality of mathematics education in Indonesia.

Fractions are one of the materials taught in elementary school. Fractions in elementary school have been expanded and deepened in the junior high school level. The problems experienced in the junior high school level was that many students did not understand the concept of fractions. Based on this, it was necessary to implement a teaching strategy that is not merely a transfer of information from teachers to students, but one which makes students understand the concept and are able to resolve problems related to daily life.

One of the learning styles that promote students to be able to construct their own knowledge is learning through Bruner's cognitive stages. Bruner stated learning is an active process that allows people to discover new things beyond the information given to them. Hawa (2014) mentioned that there were three stages of cognitive proposed by Bruner, that is, enactive, iconic and symbolic. At the enactive stage, students manipulated concrete objects. At the iconic stage, students learned by internal thoughts in which knowledge was presented through a series of pictures or graphics that done by students, relating with mental which was a picture of the real objects. The symbolic stage used symbols to understand and presented a concept. Thus, in its application, students connected their prior knowledge with the knowledge that existed in the real experience gained by manipulating learning aids. So, the concept studied would be understood by the students and then the students were able to use the concept to resolve issues related to their everyday life.

Sukayasa (2012) showed that the application of Bruner's theory could improve students' abstraction ability in understanding a concept. Research conducted by Ardika (2015) found that there were differences in learning outcomes obtained between students that learned using Bruner's learning theory and those that learned using expository learning method. In fact, students learning outcomes were better with the implementation of Bruner's learning theory.

Various models of teaching and learning media that supported better learning was being developed as an effort to improve the students' understanding of mathematical concepts. It resulted in more various learning processes using different types of media such as visual media, audio, text, mobile media and the manipulated media so that students would learn in more various ways. This meant that students did not necessarily begin with concrete objects first, students could learn through images, videos and various other types of media. The use of a wide variety of instructional media such as video or other digital media would engage students in thinking and do more effectively activities in learning mathematics than the traditional way that was done by just reading books (Sudiarta and Sadra, 2016). The successful application of Bruner's cognitive stages to improve student learning outcomes with the order "enactive, iconic, symbolic" motivates the researchers to apply Bruner's cognitive stages in a different order. Sagala (2010) also states that Bruner did not develop a systematic theory of learning, the most important was how students selected, maintained, and transformed the information that they obtained. The Bruner's cognitive stages that would be studied here was on the order "enactive, iconic, symbolic", "iconic, enactive, symbolic" and "symbolic, iconic, enactive".

In the enactive stage, the presentation is done through the direct actions of children in object manipulation (tinkering). Children learn knowledge actively, using concrete objects or a real situation. For example, when students learn the concept of comparing fractions, they are given fractions learning aids and they express fractions by shading it then compare these fractions by looking at the shaded area.

In the iconic stage, the presentation is based on the internal mind in which knowledge is presented through a series of pictures or graphics that done by the students. But, they do not manipulate the objects directly as done by students in an inactive stage. The iconic stage is a stage of learning knowledge in which the knowledge is presented in the form of visual images (visual imaginary), images or diagrams.

At the symbolic stage, learning is presented in the form of abstract symbols, that is, the arbitrator symbols which are used by consensus of people in the areas concerned, both verbal symbols (e.g., letters, words, sentences), mathematical symbols, or symbols of other abstracts. For example, when students learn the concept of comparing fractions, students are given the opportunity to learn the material comparing fractions using mathematical symbols to compare fractions, as well as how the application of the concept to resolve a problem related to the concept.

There are some common principles in a study, such as, the principle of development where this principle relates to the ability of children as they progress, so it is expected that the learning should be adapted well based on the level of individual development, the second is the principle of individual differences that teachers should be aware of the difference of each participant in terms of learning styles, characters, talents, and the third is the interests and needs of students where it should be noted by the teachers as this will affect the student's motivation in learning. The success of the student in learning depends also on internal factors of students themselves. One of the internal factors that are given less attention by the teacher in the psychological aspects that influences learning success are self-confidence. Self-confidence or known as self-efficacy by Bandura (1997) is defined as a person's belief in its capacity to organize and implement actions to achieve the set goals and trying to assess levels and strength in all activities and contexts. So, self-efficacy is a factor that greatly affects the student in the learning process to achieve the learning objectives. Research conducted by Liu and Koirala (2009) showed that there was a positive relationship between self-efficacy and mathematics academic achievement of the student. Students with a high level of self-efficacy would have a high mathematics achievement. In addition, the results of the analysis also showed that the mathematics achievement can be predicted by the self-efficacy. Thus, this study will examine more deeply about students' understanding of mathematical concepts viewed from students' self-efficacy.

2. Materials and Methods

The study examined the effect of Bruner's cognitive stages in learning mathematics on students' understanding of the fractions concept based viewed from students' self-efficacy. In this case, the experimental classes were given Bruner cognitive stages, namely "enactive, iconic, symbolic", "iconic, enactive, symbolic" and "symbolic, iconic, enactive". This study was a mixed method, as the study combined the results of statistical analysis of quantitative and qualitative research findings (Creswell, 2009).

The present study used mixed method research design of Explanatory Sequential type. The first stage of this strategy was collecting and analyzing quantitative data then followed by collecting and analyzing qualitative data based on the initial results of the quantitative data. Weights or priority was given to quantitative data (Creswell, 2009). The design of the study as follows.

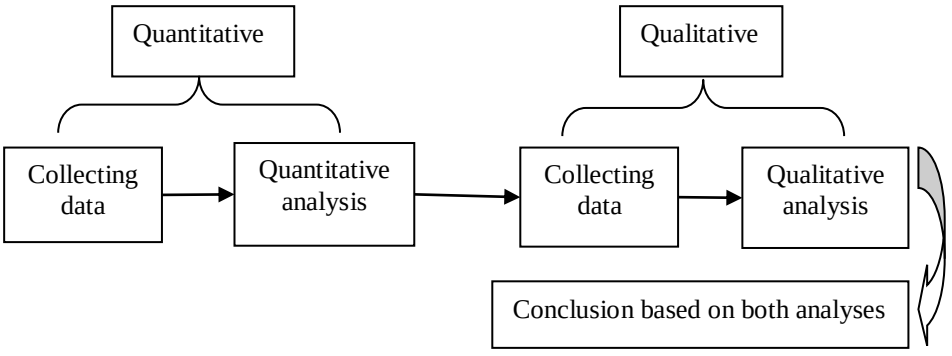

Figure 1. Mixed Method Explanatory Sequential type research design

The purpose of using Mixed Method Explanatory Sequential type research design in this study was to determine the students' understanding of the fractions concept who took the learning through Bruner's cognitive stages viewed from students' self-efficacy. In this study, test of the concept understanding was used to measure whether there were differences in the influence of Bruner' cognitive stages with the stages "inactive, the iconic symbolic", "iconic, enactive, symbolic" and "symbolic, iconic, inactive" to students' understanding of the fractions concept, as well as to determine Bruner's cognitive stages which give the best influence on the students understanding of the fractions concept. After that, a case study was done to determine the association of self-efficacy on students' understanding to the concept.

Quantitative research used the completely randomized design of experiments (completely randomized design). The use of completely randomized design (CRD) aimed to determine whether there were differences in the effect of Bruner's cognitive stages on students' understanding of the fractions concept. Under CRD design, all samples or experimental units are given treatment (Montgomery, 2001). The population of this study were students of grade VII SMP Negeri 2 Semarapura consisted of nine classes and samples were taken three classes with cluster random sampling technique.

The data collected in this study were the data of understanding the fractions concept and student self-efficacy data. The instrument used to collect the data of understanding the fractions concept was a test in the subject matter related to fraction material in a description form test (essay) with indicators of understanding of the concept according to the NCTM (2000) as follows. (1) Declaring the concept with their own words. (2) Identifying or giving examples or not an example of the concept. (3) Applying/using the concept properly in various situations.

The instrument was used to collect the data was a questionnaire self-efficacy indicators: (1) students confident in their ability to new and different problem; (2) students confident in their ability to mobilize the motivation inside themselves; (3) the student confident in its ability to discuss; (4) students confident in his ability to complete a task.

Prior to the testing carried out to obtain conclusion, the data obtained must meet the test of prerequisites, namely: (1) Normality Test to score students' understanding of the fractions concept using the Kolmogorov-Smirnov test aimed to determine the normal distribution of data; (2) Homogeneity test was done using the Levene test to finding out that two or more groups of data samples which came from populations having the same variance.

The hypothesis testing in this study used ANOVA to examine the mean difference between more than two groups of samples involving one or more independent variables and a dependent variable. ANOVA one way was used to test whether there were differences in the effect of Bruner's cognitive stages towards the students understanding of the fractions concept by comparing the value of Fcalculation ($F_{calculation}$) with value of F_{table} on the significance value $5\%(F_{0,05})$. If $F_{calculation} > F_{table}$ it was interpreted that there was a difference and if $F_{calculation} < F_{table}$ it was interpreted that there is no difference. If the null hypothesis was rejected and the alternative hypothesis was accepted, then the question that arise now was which mean that was significantly different or which one is better. ANOVA could not answer this question. Statistically, the mean difference could not be determined only by large or small the value of mean, but must go through a specific statistical tests. the It means, even if the mean of several groups had expressed differently based on the ANOVA result, advanced statistical tests were still needed. This study used the Scheffe test as the statistical test.

3. Results and Discussions

Based on the results of hypothesis testing through ANOVA, it is found that there were differences in students' understanding of the fractions concept between the students who learned using the Bruner's cognitive stages with the order of "symbolic, iconic, enactive", "iconic, enactive, symbolic", and "enactive, iconic, symbolic". Furthermore, to determine which of the Bruner's cognitive stages gave the best effect to the students' understanding of the fractions concept, further tests were conducted using Scheffe test. Scheffe test performed on a comparison of mean on students' understanding of mathematical concepts that the mean on student' understanding of mathematical concepts. Based on these results it could be concluded that the students' understanding of mathematical concepts better if using Bruner's cognitive stages with the order of "enactive, iconic, symbolic". Summary of ANOVA and Scheffe test are presented in Table 1.

Table 1
ANOVA Summary and *Scheffe* Test Summary

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13332.506[a]	2	6666.253	26.189	.000
Intercept	290879.581	1	290879.581	1.143E3	.000
Class	13332.506	2	6666.253	26.189	.000
Error	24181.983	95	254.547		
Total	328490.000	98			
Corrected Total	37514.490	97			

a. ANOVA Summary

Class	F_{count}	F'	Comment
B_3 and B_1	52.28	6.18	$B_3 > B_1$
B_3 and B_2	15.36	6.18	$B_3 > B_2$
B_2 and B_1	11.70	6.18	$B_2 > B_1$

b. *Scheffe* Test Summary

The learning process in this study applied Bruner's cognitive stages with the stages i.e. "enactive, iconic, symbolic", "iconic, enactive, symbolic", and "symbolic, iconic, enactive". At the stage of "enactive, iconic, symbolic" students learned to start from concrete objects, and then understanding through the characteristics or traits, such as images or charts, then using symbols to express, maintain and apply the concepts that they had been understood. At the stage of "iconic, enactive, symbolic" student learning began from the characteristics or traits, images or graphics, the students searched for information related to the characteristics or images, then manipulated the learning aids associated with the concept that being studied and then expressed and defended with math symbols to solve the problems given. At the stages "symbolic, iconic, enactive", at the beginning the students were given a concept examined with symbols, then the students searched information such as traits or characteristics, images or graphics, and then manipulate the learning aids associated with the concept being studied, maintaining and applying the concepts learned to solve the problem. So it could be seen the difference in the students' learning process to understand the fractions concept.

The research findings showed that the students' understanding of the fractions concept that was learned through Bruner's cognitive stages with the order "enactive, iconic, symbolic" was better than those that were learned through Bruner's cognitive stages with the order "iconic, enactive, symbolic" and the order "symbolic, iconic, enactive". The learning process with the order "enactive, iconic, symbolic" gave a lot of experience to manipulate learning aids so that students would find problems that require critical thinking to solve it, it affects the students' understanding of concepts would be better because students were more capable of resolving problems related to the concept and restating a concept, comparing with the learning sequence "iconic, enactive, symbolic" or "symbolic, iconic, enactive". In a class that learned with the order "iconic, enactive, symbolic" at the beginning the students were given rendered images that would lead students to discover concepts learned, and then manipulated props, at this stage students simply manipulated props based on the rendered images without having to search again other problems deals with the fractions concept that was studied, so when they were given the different problems they have difficulties to understand the problems and find solutions to these problems. Different things happened in applied learning with the order "symbolic, iconic, enactive", where students understood the concept based on symbols, and then observed the images were given, followed by manipulating learning aids, so in practice the students became more reluctant to manipulate learning aids as they would accept the concept given without having to manipulate the learning aids. This made the students faced difficulties when they re-state the concept of demonstration in their own words.

Based on these descriptions, it had been proved that learning using Bruner's cognitive stages with the order "enactive, iconic, symbolic" was better than learning using Bruner's cognitive stages with the order "iconic, enactive, symbolic" and "symbolic, iconic, enactive ". In the study group using Bruner's cognitive stages with the order "enactive, iconic, symbolic" was found self-efficacy by category, there are 12 high, 10 medium, and 10 low. Furthermore, to complement the quantitative data, for each category of self-efficacy was taken three students to be interviewed. The results of the qualitative analysis showed that there was a positive relationship between students' self-efficacy students' understanding of the fractions concept. Transcript of interview of one subject with high self-efficacy is shown as follows. Note that R refers to researcher and S refers to the student.

R : I noticed that you can answer the questions that I have given, then why you won't respond or write your answer on the board, why you need to be asked to do it first?

S : Yes Miss, I'm just lazy, because I'm not comfortable just go ahead if Miss does not appoint first, if I answer and go forward to answer the question, I'm afraid that my friends will mock me as Mr. know it all, Miss.

R : Do not always think that way, if you can answer show to your friends and teacher that you can answer the questions provided, besides to obtaining the active mark you also will be known by the teachers and friends from different elementary school with you, in addition, it also support you to be more confident and train you to deliver answers in front of the crowd and you will be more familiar with the material that you have learned and you can also give example to your friend to answer the questions of the teacher.
S : Yes, Miss.

This shows that the students can actually do well, just does not want to respond or work on the board, because he felt shame to the others.

Transcript of interview of one subject with medium self-efficacy is shown as follows. Note that R refers to researcher and S refers to the student.

R : I notice that you're good at answering questions with learning aids in re-stating the concept, which one from the given problem that you can not answer?
S : Yes Miss, I do not understand story problem about land dividing, it is a too long story.
R : I see, so you do not understand the question. How far you can understand that question?"
S : I understand that the father will divide a land of 600 m^2, then he gives it to three of his children. However, it only two lands of the children known, then I am looking for the area of those two land by multiplying the fraction of the children to 600.
R : Yes, that's right, then why you do not continue to answer the question, if you know the area of those children it will be easy for you answer the question, right?
S : Nah, that part I do not understand Miss. How can I determine the portion of the third child, if there are only two portions for the two children, how the portion of the father, I also do not know?
R : Ok, now you try to read the question again, the father has a land 600 m^2 which all of them will be given to his children. From that sentence how many that the father has from his land?
S : All the parts were owned by the father then it will be divided.
R : Yes that's right, the father has all the parts of the land, in the fractions learning aid all the parts are shaded. What does it mean? (the researcher draw the father portion through fractions learning aid images)
S : Oh, ya. It means that the father's portion is 1 Miss? It means that the third child's part with this way 1 minus $\frac{1}{3}$ then minus $\frac{2}{3}$, I have just got it. Actually, I just go near to the answer.
R : Finally you got the answer, next time you need to be carefully reading the question, you need to understand every single sentence to make you understand the whole question.
S : Yes, Miss.

According to the student's response above, it shows that the student does not understand the question, so he can not solve the problem.

The learning process using Bruner's cognitive stages with the order "enactive, iconic, symbolic" gave students an opportunity to construct their knowledge by discussing in a group. The students would understand and resolve problems which they faced through discussion in with friends in their group, then they would gain experiences to achieve a successful learning. These experiences of success to solve the problem with various conditions was a source of self-efficacy which was called the mastery experiences by Bandura (1997). In the learning sequence "enactive, iconic, symbolic" the students would find various problems when manipulating props to understand a concept, so in that situation, the students with high self-efficacy had the motivation to solve the problems given, while the students with low self-efficacy would tend to give up and avoid these problems.

In the learning process which was conducted by group discussion, the students constructed knowledge together, that allows them to learn by sharing knowledge, the students who understand the concept would contribute to the current discussion and the other students would pay attention to the students with greater capacity who were able to resolve the problems given, according to Bandura (1997) that was a source of self-efficacy with the experience of another individual (vicarious experience). Vicarious experience is a source of self-efficacy from the experience of someone's success, students with high self-efficacy will strive to succeed in solving the problems, while students with low self-efficacy will tend to wait for the results from the other smart students.

The condition of students' physical and psychological state to face a task in various situations also affected the students' self-efficacy, it is referred to as the experience of success (Physiological state) by Bandura. In the

application of Bruner's theory in the order "enactive, iconic, symbolic" the students would face problems in various conditions which would affect the physical and psychological state of students in dealing with problems, the students with low self-efficacy would encounter the situations by feeling anxious, depressed and dispirited even avoid problems/ questions/ tasks, however, the students with high self-efficacy would be interested, eager to solve problems/ questions/ tasks assigned.

In the learning with sequence of Bruner' cognitive stages" enactive, iconic, symbolic" the role of the teacher is only as facilitators and motivators in the learning process, teachers would only help when students have difficulty in an indirect way to provide answers to the problems faced by leading the students to be able to find the solution of these problems. In that process teachers gave the students persuasion and motivation that they were able to solve it independently. According to Bandura (1997), that situation was a source of self-efficacy called verbal persuasion (verbal persuasion). The students with high self-efficacy would be confident to be able to resolve the problems faced by persuasion and support given by teachers, while the students with low self-efficacy would feel depressed and just be silent because students feel that teachers did not help at all.

Based on these descriptions, it seen how the linkage application of the Bruner's theory in the order "enactive, iconic, symbolic" with the students' self-efficacy in the learning process that affected the students' understanding of the fractions concept where the students with high self-efficacy would have a high understanding of the fractions concept and the students with low self-efficacy would have a low understanding of the concept. The results of this study reinforced and complemented the results of the previous findings by Liu and Koirala (2009) which showed that there was a positive relationship between self-efficacy and academic achievement of student mathematics. This was also consistent with the theory which was stated by Bandura (1997), where there were four psychological processes in self-efficacy would play a role in human beings.

Firstly is a cognitive process that is the process of thinking, therein including the acquisition, organization, and use of information. Individuals who have high self-efficacy would be happier to think about success. Instead of individuals who have low self-efficacy would tend to imagine failures and the obstacles which can hamper the success. The forms of personal goals are also influenced by the self-assessment to individual's capability. The more a person perceives himself capable then that individual will increasingly shape the efforts to achieve his goal shave stronger commitment to the goal.

Secondly is the motivation process that is most of the human motivation raised through cognitive. Individuals provide motivation/ encouragement for themselves and drive action through a phase of prior thinking. The ability of self-efficacy can affect motivation in some ways, that determines to set goals of individuals, how much work is done, how they hold up in the face of difficulties and their resilience to face the failure.

Thirdly is the effective process that is the process of setting the emotional conditions and emotional reactions. According to Bandura (1997) individual beliefs to 'coping' also influence a person's stress levels and depression when they face a difficult situation. The perception of someone's self-efficacy about their ability to control the sources of stress has an important role in raising the anxious.

Lastly is the selection process that is the ability of individuals to choose the activity and the specific situation also influences the effects of an incident. Individuals tend to avoid activities and situations that are beyond their ability. When individuals feel confident that they are able to handle a situation, they tend not to avoid the situation. Having the choice made, then the individual can improve their skills, interests, and their social relationships.

4. Conclusion

Based on the results of hypothesis testing and discussion in this study it could be concluded as follows. (1) There were differences in students' understanding of math concepts that learned to use Bruner's cognitive stages with the order "enactive, iconic, symbolic", "iconic, enactive, symbolic", and "symbolic, iconic, enactive ". (2) learning fractions with the Bruner's cognitive stages with the order " enactive, iconic, symbolic" had the highest impact on the students' understanding of the concept (3) the students' self-efficacy in the learning through Bruner's cognitive stages with the order " enactive, iconic, symbolic" have a positive relationship to understanding the fractions concept.

Psychological processes such as cognitive processes, motivational, affective and selection process/selection in self-efficacy played a role in students. The students with high self-efficacy tended to have a high understanding of the fractions concept while the students with low self-efficacy tended to have a low understanding of the concept as

well. So, that the students' self-efficacy learning also needed to be considered in order to build a better learning and understanding of the concept of high students.

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Statement of authorship
The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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