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# Association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking

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**ABSTRACT**

The purpose of this research is to determine the correlation between the students' Self-Renewal Capacity and Advanced Mathematical Thinking. This research is a quantitative research with survey method. The subjects in this research were students of Mathematics Education who contracted Mathematical Statistics Course in one of the private universities in East Jakarta. Sampling technique used purposive sampling. This research used various main instruments. They were Self-Renewal Capacity (SRC) scale and test of Advanced Mathematical Thinking (AMT). The results of this research are: there is enough association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking**.**



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## 1. INTRODUCTION

Mathematical concepts in college are generally more complex than mathematical concepts in school because that concepts which is given in college is more abstract. Therefore, students of mathematics education program must have ability in constructing and finding mathematical concepts themselves, proving logically, and developing their mathematical abilities. This is very important for them in completing mathematical tasks in college, especially advanced mathematical courses [1], such as Mathematical Statistics course. To realize that expectation, students' mathematical thinking abilities should be developed and connected to mathematicians' thinking in order to create Advanced Mathematical Thinking abilities that focus more on formal definitions, logical deductions, and creative thinking [2]. Advanced Mathematical Thinking ability include several components. There are representation, abstraction, connecting between representation and abstraction, creative thinking, and mathematical proof [1]. However, the student' Advanced Mathematical Thinking, especially in Mathematics Statistics course, is still relatively low.

Based on the results of Marron [3] and Petocz & Smith [4] studies that students of mathematics education program in Mathematical Statistics course have difficulties in mathematical proving process. In addition, based on the results of Suryana's [5] study that students have difficulty in studying mathematical statistics course, such as in presenting problems into other forms, generalizing, trying other ways of solving problems, reading mathematical proof, and constructing mathematical proof. In reading mathematical proofs, Suryana [6] in his study also revealed that students have difficulty in checking the truth and writing the concept which is used in each step of proof in Mathematical Statistics course.

To develop Advanced Mathematical Thinking abilities, students have to make improvements to their performance in learning Mathematical Statistics. They must try to develop their Self-Renewal Capacity. Saarivirta [7] and Bustanul [8] revealed that Self-Renewal Capacity is one's capacity to improve its

performance in learning through exploitation, exploration, absorption, integration, and leadership. When students have a high Self-Renewal Capacity, students will always use their self-potential and all the information available for learning purposes, have a high curiosity to new something relatively, able to adapt and socialize with new environmental conditions, and have a high leadership. It is predicted that students can develop the ability of their Advanced Mathematical Thinking. Otherwise, students who have low Self-Renewal Capacity will difficulty in learning, lazy to learn a new something, to be individualist, and have a low leadership. It is predicted that students can not develop the ability of their Advanced Mathematical Thinking.

To find out more about the association between students' Self-Renewal Capacity and Advanced Mathematical Thinking, the researcher is interested in doing a research about it. In this research, the students' Self-Renewal Capacity and Advanced Mathematical Thinking were grouped into 3 categories, namely high, medium, and low. This research has a high originality because Self-Renewal Capacity has not been studied yet in mathematics education. In addition, Advanced Mathematical Thinking also has not been studied yet in Mathematical Statistics course. The purpose of this research is to know about the association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking. This research is expected that it can be a reference and discourse for the practitioners of mathematics education in knowing about the association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking.

## 2. LITERATURE REVIEW

### 2.1 Advanced Mathematical Thinking (AMT)

According to Dreyfus [2], Advanced Mathematical Thinking is a process of mathematical thinking that includes representation, abstraction, and the relationship between representation and abstraction process. Ervynck [2] said also that creative thinking has an important role in Advanced Mathematical Thinking process. Creative thinking has contribution in deduction process. In the process of deduction, creative ideas is needed based on experiencing in the mathematical context. Sumarmo [1] and Harel & Sowder [9] said also that Advanced Mathematical Thinking is an ability that includes representation, abstraction, relationship between representation and abstraction, mathematical creative thinking, and mathematical proof.

Furthermore, Sumarmo [1] says that the development of Advanced Mathematical Thinking abilities is more emphasized for students of college, but in some cases, the Advanced Mathematical Thinking process has been introduced to students of high school. The level of verification in Advanced Mathematical Thinking according to Mason [1] are: (1) convice yourself, that is related in "why a statement is true"; (2) convince a friend, that is related in "how to convince others with coherently organized arguments"; and (3) convince an enemy, that is related in "how to convince others with a coherently organized, analyzed, and refined argument that is ready to be criticized".

Based on Advanced Mathematical Thinking description above, Advanced Mathematical Thinking (AMT) in this research is an ability that includes representation, abstraction, creative thinking, and mathematical proving. In this research, the indicator for measuring mathematical representation is 'presenting the problem in another form', and the indicator for measuring mathematical abstraction are 'generalizing' and 'synthesizing'. Meanwhile, indicators for measuring mathematical creative thinking are 'fluency', 'flexibility', 'originality', and 'elaboration'; and the indicator for measuring mathematical proof are 'reading mathematical proofs' and 'constructing mathematical proofs'.

### 2.2 Self-Renewal Capacity (SRC)

Self-renewal is one of the seven habits that is needed by every human to be effective [10]. Effective human is a person who has an ability to think effectively. According to Sumarmo [11], the ability to think effectively can not be seen directly, but it can be analyzed through thoughts and productive activities. Costa and Garmston [11] classify thoughts and productive activities into five human passions, namely: (1) the ability to self-control and to have self-confidence; (2) flexibility in acting; (3) proficiency in thinking; (4) awareness of what they do and its impact on the environment; and 5) to have relationship with other person as social beings. Self-renewal is useful for improving self-potential [10].

Self-renewal development of each person depends on their capacity in thinking and acting. Capacity is defined by Goodman [12] as the ability to execute goals. According to Milen [13], capacity is defined as the ability of individuals to perform their functions effectively, efficiently, and constantly. Meanwhile, according to Morgan [13], capacity is defined as an ability, skill, understanding, attitudes, values, relationships, behaviors, motivations, and conditions that each person can perform their functions to achieve the goals that have been established from time to time.

Self-renewal development that is adapted with its' capacity is called Self-Renewal Capacity. The Self-Renewal Capacity concept was first presented by Sotarauta and Stahle [7]. According to Sotarauta [7], Self-Renewal Capacity is a series of processes that is designed for the future. That is a process of adaptation. Self-Renewal Capacity can be seen as a set of abilities that aim to create self-renewal. Meanwhile, Stahle [7] defines

Self-Renewal Capacity as the overall capacity of individuals to master change, such as mastering a new strategy, developing information or knowledge, and creating innovation. Furthermore, Bustanul [8] revealed that Self-Renewal Capacity is a capacity of person to always improve and perfect their work through learning process and empirical reflection. Sotarauta [7] outlines 5 Self-Renewal Capacity indicators, namely: exploration, exploitation, absorption, integration, and leadership.

Based on Self-Renewal Capacity description above, Self-Renewal Capacity (SRC) in this research is the capacity of a person to improve their performance in learning through exploration, exploitation, absorption, integration, and leadership. The sub-indicator of the exploitation in this research are 'to utilize all information for a particular purpose' and 'exploit the self-potential'. The sub-indicators of the exploration in this research are 'have creative ideas', 'have an interest in generalization, proof, and representation process', and 'have a high curiosity about new something relatively'. The sub-indicator of absorption in this research is 'adaptation'. The sub-indicators of the integration in this research are 'respect for others', 'prioritizing of common interests', and 'self-controlling of the conflict'. Meanwhile, the sub-indicator of the leadership are 'working hard in solving problems', 'having strong motivation', 'having communication skills', 'making decisions in solving problems', 'being responsible', and 'meticulous in doing something'.

## 3. RESEARCH METHOD

This research was conducted at one university in East Jakarta. This research used quantitative method. The sample in this research were the students of Mathematics Education Program that have accomplished Mathematical Statistics course in the academic year of 2013/2014. The number of samples that was used in this research were 68 students. The sampling technique used purposive sampling. Sources of data in this research were students as samples. The main instruments that was used in this research were Self-Renewal Capacity (SRC) scale and test of Advanced Mathematical Thinking (AMT). That instruments have been validated, so that it can be used in this research. Meanwhile, this research used also additional instruments that aim to deepen the analysis. There were observation sheets and interview guides.

Method of main data collection used scale of attitudes (SRC) and Essay test (AMT). Technique of data analysis used descriptive and association analysis. For descriptive analysis, SRC and AMT data were grouped into 3 categories, namely: high, medium, and low. The grouping rules was adapted from Noer [14], namely:

**Table 1. Category of Students' SRC and AMT**

| Score of AMT Test or SRC Scale ($X$) | Category |
|---|---|
| $X \geq 70\%$ | High |
| $60\% \leq X < 70\%$ | Medium |
| $X < 60\%$ | Low |

If it has been grouped, the number of students in each category were placed in the contingency table for descriptive analysis process. Meanwhile, for association analysis, it used test of hypothesis that aim to strengthen the findings descriptively. Interpretation of association degree is given in the following table [15]:

**Table 2. Interpretation of Association Degree**

| Association Degree ($C$) | Interpretation |
|---|---|
| $C = 0$ | Have Not Association |
| $0 < C < 0,2C_{\max}$ | Very Low |
| $0,2C_{\max} \leq C < 0,4C_{\max}$ | Low |
| $0,4C_{\max} \leq C < 0,6C_{\max}$ | Enough |
| $0,6C_{\max} \leq C < 0,8C_{\max}$ | High |
| $0,8C_{\max} \leq C < C_{\max}$ | Very High |
| $C = C_{\max}$ | Perfect Association |

## 4. RESULTS AND ANALYSIS

### 4.1. Results

Descriptive analysis through contingency table about association between students' Self-Renewal Capacity (SRC) and Advanced Mathematical Thinking (AMT) is given in Table 3. Data that is analyzed is taken from the final SRC scale and post test of AMT.

**Table 3. Association between students' SRC and AMT**

| SRC | Stat. | AMT | | | |
|---|---|---|---|---|---|
| | | High | Medium | Low | Total |
| High | $f_o$ | 7 | 11 | 7 | 25 |
| | $f_h$ | 2,6 | 8,8 | 13,6 | 25 |
| Medium | $f_o$ | 0 | 12 | 30 | 42 |
| | $f_h$ | 4,3 | 14,8 | 22,9 | 42 |
| Low | $f_o$ | 0 | 1 | 0 | 1 |
| | $f_h$ | 0,1 | 0,4 | 0,5 | 1 |
| Total | $f_o$ | 7 | 24 | 37 | 68 |
| | $f_h$ | 7 | 24 | 37 | 68 |

**Note:**
$f_o$ = frequency of observation
$f_h$ = frequency of expectation
$f_h = \frac{\sum B_i \sum K_i}{N}$ with $B$ is row and $K$ is column

Based on the table, it can be seen that students who have high SRC are more dominant have medium AMT. Meanwhile, students who have medium SRC are more dominant have low AMT. But, students who have low SRC are more dominant have medium AMT. Based on the results of that analysis, it was not seen significantly that there is association between the students' SRC and AMT. To reinforce the finding of the association between students'AMT and SRC descriptively, then the data are tested statistically. The hypothesis that is tested are given below:

$H_0$: There is no association between the students' SRC and AMT
$H_1$: There is an association between the students' SRC and AMT

Testing criteria of this research are: if $\chi^2_{value} > \chi^2_{table}$ then reject $H_0$, and if otherwise, then accept $H_0$ [16].

To know about " is there an association between students' AMT and SRC?", it can be done by Chi Square test. However, it is recommended that adjacent rows or columns in Table 3 must be combined before being analyzed because: (1) there are zeros in cells of Table 3; (2) some frequency of expectation in sells of Table 3 are below 1; and (3) some frequency of expectation that are less than 5 in sells of Table 3 are exceeds 20%, so that frequency of expectation in sells of Table 3 are more than 5 after the cells of it are combined [15]. The table that formed as a result of this correction is given in Table 4.

**Table 4. Correction about Association between students' SRC and AMT**

| SRC | Stat. | AMT | | |
|---|---|---|---|---|
| | | High & Medium | Low | Total |
| High | $f_o$ | 18 | 7 | 25 |
| | $f_h$ | 11,4 | 13,6 | 25 |
| Medium & Low | $f_o$ | 13 | 30 | 43 |
| | $f_h$ | 19,6 | 23,4 | 43 |
| Total | $f_o$ | 31 | 37 | 68 |
| | $f_h$ | 31 | 37 | 68 |

**Note**: $f_o$ = frequency of observation and $f_h$ = frequency of expectation

Based on the table, it appears that the size of the table cell becomes 2x2 and the number of respondents are 68 students. Therefore, the determination of the chi-square value used the formula of Yates correction. According to Cochran [17], Yates correction is used for 2x2 contingency tables and the number of respondents ($N$) are over 40 to determine the chi-square value. According to Siregar [15], if the correction table has a form:

**Table 5. *Yates* Correction**

| | $K_1$ | $K_2$ | Total |
|---|---|---|---|
| $B_1$ | $a$ | $b$ | $\sum R_1$ |
| $B_2$ | $c$ | $d$ | $\sum R_2$ |
| **Total** | $\sum C_1$ | $\sum C_2$ | $N$ |

**Note:** $R$ = Row and $C$= Column

Then the chi-square value is obtained from the formula:

$$\chi^2_{value} = \frac{N\left(|ad-bc|-0,5N\right)^2}{\sum R_1 \sum R_2 \sum C_1 \sum C_2}.$$

So the value of $\chi^2_{value}$ is 9,50. Meanwhile, the value of $\chi^2_{table}$ for $\alpha$ = 0,05 and $df$ = ($R$-1) ($C$-1) = 1 is 3,841. It can be seen that value: $\chi^2_{value} > \chi^2_{table}$, so the null hypothesis is rejected. This means that there is an association of both variables [15]. In other words, there is an association between the students' Self-Renewal Capacity (SRC) and Advanced Mathematical Thinking (AMT). To determine the association degree of two variables, the contingency coefficient ($C$) and $C_{\max}$ values should be searched. $C$ and $C_{\max}$ values are obtained from the formula [15]:

$$C = \sqrt{\frac{\chi^2}{\chi^2+n}} \quad \text{and } C_{\max} = \sqrt{\frac{m-1}{m}}$$

**Note**:

$\chi^2 = \chi^2_{value} =$ value of chi-square

$n =$ amount of sample

$m = \min\{\text{amount of row, amount of column}\}$

By using the formula above, then that is obtained: value of $C$ = 0,35 and $C_{\max}$ = 0,71. Furthermore, to determine the association degree of the two variables, that is required value of $C/C_{\max}$, and its' value is 0,49. The value can be written in the form: C = 0,49 $C_{\max}$, and the association degree of it is enough [15]. Based on the results of that analysis, it can be concluded that there is an association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking with enough category.

### 4.2. Analysis

The results show that there is an association between students' Self-Renewal Capacity (SRC) and Advanced Mathematical Thinking (AMT). These findings are based on statistical test results. These results indicate that if students have high SRC, then they also have high AMT and if students have low SRC, then they also have low AMT. The association between students' SRC and AMT can be seen from sub-indicator 'exploration' on SRC and components of AMT. If person has creative ideas, has an interest in the process of generalization, proof, and representation, and has a high curiosity about new something relatively, then they can develop representation, abstractions, creative thinking, and mathematical proofs ability. Otherwise, if person hasn't creative ideas, hasn't an interest in the process of generalization, proof, and representation, and hasn't a high curiosity about new something relatively, then they can not develop representation, abstractions, creative thinking, and mathematical proofs ability well.

The results of this analysis are reinforced by the findings of Suryana [18] about the achievement and enhancement of indicators of AMT which concluded that indicator 'generalizing' in the component of AMT has a relatively low achievements and enhancement than other indicators of AMT. In addition, it was also found that the sub-indicator 'have an interest in generalization' in SRC has a relatively low achievement and enhancement than other sub-indicators of SRC [18]. Based on the results of this research, it appears that 'generalizing' and 'have an interest in generalization' is still relatively low. This shows that students are still weak in choosing a suitable strategy to find the general pattern or form of some equation (generalizing). As a consequence, the students are less interested in generalizating. In other words, there is an association between students' SRC and AMT.

The association between the students' SRC and AMT can also be seen from sub-indicator 'leadership' in SRC and one component of AMT. If someone has a ability to represent problems in other forms (visual, verbal, and mathematical notation) well, it will support to develop communication skills. Otherwise, if

someone hasn't a ability to represent problems in other forms (visual, verbal, and mathematical notation) well, it will not support to develop communication skills. This is reinforced by Hudiono [19] that representations can assist students in communicating mathematical concepts. Meanwhile, according to Baroody & Niskayuna [20], one aspect contained in the ability of mathematical communication is a representation.

Although based on the results of this research showed there is an association between students' SRC and AMT, but the association degree of it has enough category. In other words, the association between students' SRC and AMT is not very high. The cause of it can be seen in Table 3. The table shows that students who have high SRC was more dominant to have medium AMT. Meanwhile, students who have a medium SRC was more dominant to have low AMT. But, students who have low SRC was more dominant to have a medium AMT. This finding is quite interesting because ideally, students with high SRC should be more dominant to have high AMT. Otherwise, students with low SRC should be more dominant to have low AMT. That ideal conditions will produce a high association degree.

For students with high or medium SRC, their AMT ability is below their SRC level. It happens because the students' SRC has grown before they take Mathematical Statistics course. Exploitation, exploration, absorption, integration, and leadership that are owned by students have actually been formed in the previous course, so even though the student has a medium or low AMT, the SRC has grown well before learning. This can be seen from students' efforts and hard work to study Mathematical Statistics even though the results are still not satisfactory. The findings are reinforced by the results of interviews with representatives of students with low and medium AMT that they have actually tried to explore their potential to learn, work hard, discuss with friends, and try to explore, but they still have difficulty in solving AMT problems and the results are still not satisfactory. This finding is similar to the findings of previous studies, that there is sufficient association between students' cognitive and affective aspects [16][21].

However, there is one illogical finding, the finding that one student has a low SRC, but he has medium AMT (See Table 3). The researcher tried to interview that student and the result was different from what he wrote on the SRC scale. The student may be less open about his condition or attitude in writing. As expressed by Ruseffendi [22] that openness, subjectivity, and relevance are things that must to be noticed when someone expresses his attitude. Apparently, the student admitted that his SRC has grown well and his AMT ability has medium category. This finding reinforces the result that there is an association between the students' SRC and AMT with enough category.

## 5. CONCLUSION

The conclusion of this research is there is an association between the students' Self-Renewal Capacity and Advanced Mathematical Thinking with enough category. In order to have a high association or more, innovative learning in Mathematical Statistics course is very needed in supporting the students' SRC and AMT development.

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