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# Cognitive Development of Mathematics Education Students based on Piaget's Theory in terms of Gender Differences

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**Abstract**

This study aims to understand the cognitive development of mathematics education students based on Piaget's theory in terms of gender differences. This research method is descriptive quantitative research with the research subjects being students of mathematics education at Timor Universities. Students' cognitive development was measured using the Logical Operations Test (LOT), which consisted of 14 numbers. LOT questions are given to students, the results are analyzed and described. The results showed that the cognitive development stage for females was 19.18% in the initial concrete stage, 36.99% in the final concrete stage, 13.70% in the initial formal stage and 1.37% in the final formal stage. Male at 9.59% in the initial concrete stage, 6.85% in the final concrete stage, 9.59% in the initial formal stage and 2.74% in the final formal stage. Meanwhile, students' understanding based on seven logical operations is in low understanding for each type.

***Abstrak***

*Penelitian ini bertujuan untuk mengetahui perkembangan kognitif mahasiswa pendidikan matematika berdasarkan teori Piaget ditinjau dari perbedaan jenis kelamin. Metode penelitian ini adalah penelitian deskriptif kuantitatif dengan subjek penelitian adalah mahasiswa pendidikan matematika Universitas Timor. Perkembangan kognitif mahasiswa diukur dengan menggunakan Tes Operasi Logis (TOL) yang berjumlah 14 nomor. Soal TOL diberikan kepada mahasiswa, hasilnya dianalisis dan dideskripsikan. Hasil penelitian menunjukkan bahwa tahap perkembangan kognitif sebesar 19,18% tahap konkret awal, 36,99 % tahap konkret akhir, 13,70% tahap formal awal dan 1,37% tahap formal akhir bagi mahasiswa perempuan. Sementara hasil pemetaan tahap perkembangan kognitif sebesar 9,59% tahap konkret awal, 6,85 % tahap konkret akhir, 9,59% tahap formal awal dan 2,74% tahap formal akhir bagi mahasiswa laki-laki. Sementara itu pemahaman mahasiswa berdasarkan 7 operasi logis berada dalam pemahaman rendah untuk masing-masing tipe.*

***Keywords**: Cognitive Development, Piaget's Theory, Gender Differences.*

## INTRODUCTION

Several studies have shown that the low mathematics learning outcomes are strongly indicated by the lack of teacher creativity in designing learning because most teachers still use conventional methods in delivering mathematics material (Hapsari, 2011; Effendi, 2012; Putra & Lutfiyah, 2020; Suarni, 2019). In addition, the current world condition is experiencing the Covid-19 disaster which has


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an impact on the education sector so that face-to-face education is reduced and replaced with online learning (on the network) (Fatimah, Asmara, Mauliya, & Puspaningtyas, 2021; Mustakim, 2020). Of course, this condition requires teachers to design distance learning as well as possible.

In designing distance mathematics learning, it is necessary to consider the students' cognitive development so that the learning design can be right on target. This is in line with the statement that teachers need to have a deep understanding of one's cognitive development so that the learning process can be following the students' cognitive level (Alvina, Sugiatno, & Suratman, 2015; Khiyarusoleh, 2016; Sidik, 2020).

Everyone has a different cognitive level from child to adult or chronologically according to the order of birth time (Piaget, 1969). In addition, this cognitive development will increase in line with the more mature a person (Jarvis, 2011). Regarding cognitive development, Piaget believed that a one's cognitive development consists of four stages, namely the sensorimotor stage (0-2 years), preoperational stage (2-7 years), concrete operational stage (7-11 years), and formal operational stage (11 years and over). At the sensorimotor stage, the child recognizes his environment with his five senses so that he reacts directly to this recognition activity. Furthermore, in the preoperational stage, children begin to use symbolic language in the form of images or spoken language that they get from learning through repetition. Then, the concrete operations stage where children apply their thoughts to concrete or real objects, not yet abstract, furthermore hypotheses. Then the last stage experienced by children is the stage of formal operations where children can reason without having to get direct movements from objects, and at this stage, children are also able to conclude from information (Amir & Risnawati, 2015).

Furthermore, previous reserch revealed that there is an influence between the selection of a strategy or learning method on Piaget's cognitive development. For example, junior high school teachers need to understand that the thinking stage of their students is still concrete so that one of their opportunities to understand mathematical material is through concrete objects. For example, students will learn about the concept of probability, the teacher can use dice and then ask students to experiment with throwing dice and note what numbers appear in $\boldsymbol{n}$ times of tossing. In addition, the material on proving theorems or theorems that require deductive or inductive thinking is given to children who are already in the formal operation stage, namely high school students and college students (I. N. Aini & Hidayati, 2017; Mutammam, 2013).

Mathematics education students who are individuals with an average age of over 11 years, of course, the learning process given to them must be deductive and more focused on abstract thinking and logical reasoning. They have entered the stage of formal cognitive development. So based on the theory described earlier, there are only two possibilities for their cognitive development, namely concrete or formal, so this study only classifies the categories of cognitive development into initial concrete, final concrete and initial formal, final formal.

Facts found in the field during lecture activities, there are still students who do not have abstract thinking and logical reasoning. This is known from the inability of students to understand abstract materials, for example, integers, linear equations, the inability of students to formulate assumptions, for example

about determining number patterns, and so on.

Based on the results of interviews, one of the factors that this happened was that these mathematics education students came from the non-Science majors while in high school which resulted in their thinking no better than those from the Science majors. This fact supports the research revealed by Russefendi that students may not or have never reached the stage of formal reasoning (Alvina et al., 2015).

Another assumption is that the lack of knowledge about the teachers' cognitive development, while they are in school, has an impact on the teachers' inability to develop learning strategies that are following their cognitive development. Or another assumption, it is possible that teachers understand Piaget's cognitive development but do not know what tests can be used to confirm one's cognitive development. Based on these assumptions, this research was conducted to prove whether mathematics education students had entered the formal operational stage or not. Through this research, prospective mathematics teacher students can also find out their respective cognitive developments so that later when they become teachers, they can develop learning strategies that are following the stages of cognitive development of their students.

Logical Operations Test (LOT) is used to measure students' cognitive development which refers to 7 patterns of logical reasoning, namely classification, serialization, logical multiplication, compensation, proportion, probability and correlation (Leongson & Limjap, 2003). First, classification is described as the basis for grouping an object based on certain properties. For example, arrange integers from smallest to largest or vice versa. Second, serialization is described as a numerical property of a number pattern. For example, determine the n-th term of a number pattern. Third, multiplication is described in making references that are applied in multiplication. For example, story questions related to multiplication operations or vice versa.

Fourth, compensation is described by providing logical reasons that can be used to balance something. Fifth, the proportion is described in determining a comparison. For example, the ratio of the number of males to females in an activity. Sixth, probability refers to the possible outcomes that arise. And the last is correlation which refers to the ability of reasoning in connecting several variables. For example, the relationship between distance, speed and time is that the longer the distance, the longer it takes at a lower speed.

In addition, this study will measure a person's cognitive development in terms of gender differences because several previous studies have shown that there are differences in cognitive development between males and females in solving LOT questions (I. N. Aini & Hidayati, 2017; Rahman et al., 2018). The research of (I. N. Aini & Hidayati, 2017) shows that more female students are in the initial formal stage with a percentage of 53.33% while male students are more in the initial and final concrete stages. The difference between previous studies and this research lies in the research subjects who are students who are theoretically already at the stage of formal cognitive development.

## METHOD

The subjects of this study were mathematics education students at the Universitas Timor totalling 73 students. The type of data in this study is quantitative, namely the data in the form of the results

of student work on logical operations test questions. The data collection technique in this study used a test in the form of essay questions totalling 14 valid numbers. The instrument of this research is LOT Piaget which has been validated.

The procedure of this research is to give validated LOT questions to students. Then the results of the work are analyzed and grouped into a stage of cognitive development. From each stage of cognitive development, each subject is grouped by gender so that it can be seen the cognitive development of each gender.

LOT consists of math problems that are arranged based on Piaget's 7 logical operations. Each logical operation is represented by 2 questions so there are 14 questions. These questions are essay questions. Subjects were given 105 minutes to complete these questions. The scope of the problem material on the LOT is mathematics subject matter that has been accepted by the subject in high school and previous education levels. The results of student answers were then analyzed based on the LOT scoring guidelines in Schoenfeld's Scoring Continuum (Leongson & Limjap, 2003) which are presented in table 1.

The students' LOT scores were then grouped based on Piaget's cognitive stage (Leongson & Limjap, 2003), as shown in Table 2 below. In addition, the students' average understanding of the LOT questions for each type of question was also given information. Low understanding of the average score is in the 0-2,16 interval, poor understanding of the average score is in the 2,1-4,16 interval, sufficient understanding if the average score is in the 4,17 interval -6.16 and high comprehension if the average score is 6.17-8.

Table 1. LOT Scoring Guidelines

| Score | Explanation |
|---|---|
| 0 | There is no effort made by the subject to solve the LOT questions. |
| 1 | Little effort is made by the subject, such as being able to form sketches, show the relation, find out data needs, or make explanations to solve problems. |
| 2 | The subject understood the problem and was able to solve the LOT questions but did not finish. |
| 3 | The subject almost finished the LOT questions and the troubleshooting steps were correct but there were still errors. |
| 4 | The subject completed the problem completely and was solved correctly. |

Table 2. Piaget's Cognitive Stage Grouping Based on LOT Score

| Piaget's Cognitive Stage | LOT Score |
|---|---|
| Initial Concrete Operation Stage | 0 – 14 |
| Final Concrete Operation Stage | 15 – 28 |
| Initial Formal Operation Stage | 29 – 42 |
| Final Formal Operation Stage | 43 – 56 |

## RESULTS AND DISCUSSION

### Research Results

Results of Mapping Piaget's Student Cognitive Development can be seen at Figure 1.

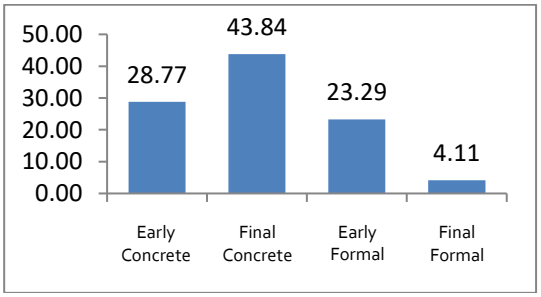


*Figure 1. Diagram of Student Piaget's Cognitive Development Mapping Results (in percent)*

Figure 1 shows that the cognitive development of mathematics education students is in the final concrete stage in the

first order, then the initial concrete stage in the second, in the third order the initial formal stage and the last sequence is the final formal stage. Only a few mathematics education students had reached the final formal stage. It is also seen that the percentage of each stage of cognitive development is not up to 50%. Most mathematics education students are still in the final concrete cognitive stage with a classical percentage of 22.28%.

Results of Mapping Piaget's Student Cognitive Development by Gender can be seen in Figure 2.

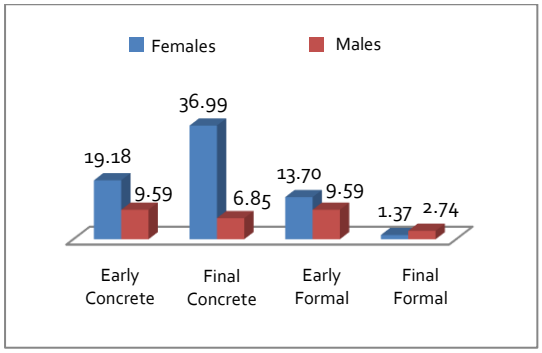


*Figure 2. Diagram of Student Piaget's Cognitive Development Mapping Results by Gender*

Figure 2 shows that there are significant differences in cognitive development between males and females. First, the initial concrete stage for the female is 19.18% while for the male it is 9.59%. Second, for the final concrete stage, 36.99% were dominated by female students, while 6.85% were male. Third, the final formal stage for the female is 13.70% while for males it is 9.59%. The last stage of cognitive development is the final formal stage for females at 1.32% while for males it is 7.74%. The initial concrete stage, final concrete and initial formal are dominated by a female. While the final formal stage is dominated by males.

Category of Understanding Piaget's LOT Questions for Mathematics Education Students can be seen in Figure 3. In Figure 3 for the classification LOT question type, there are 2.02% of males who have a low understanding, as well as 2.15% of females who have a low understanding. For the serialized LOT question type, there is 1.71% of the average score for the male who has low understanding, and 1.54% of the average score for the female who has low understanding. Furthermore, the third LOT question type is logical multiplication, there is 2.48% of the average score of males who have a poor understanding of this question, and 1.94% of the average score of the female also experience low understanding. Male and female students also experienced low understanding for the fourth LOT

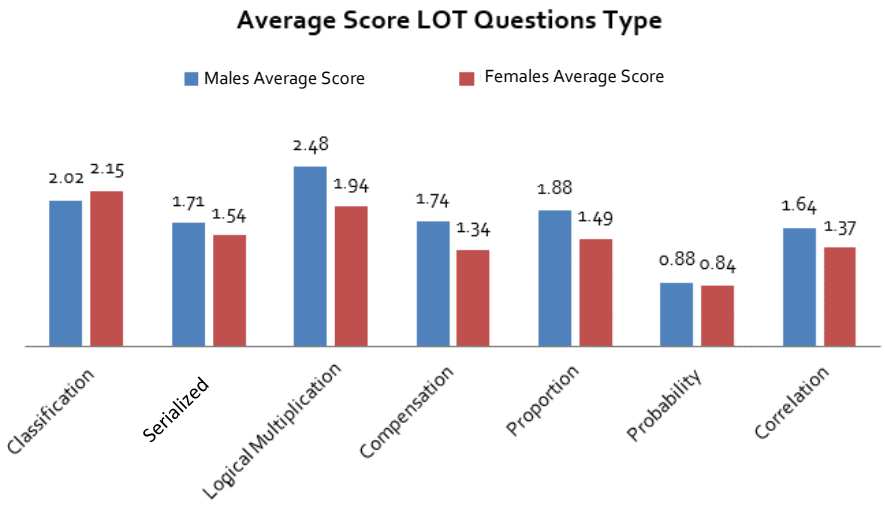


*Figure 3. Diagram of Understanding Category LOT Questions Type*

question type, namely compensation with a percentage of 1.74% male and 1.34% female. The fifth LOT questions type regarding proportions also received low understanding from male and female students with a percentage of 1.88% male and 1.49% female. Furthermore, the sixth LOT questions type, namely the probability of obtaining a low understanding for male students, is 0.88% and for female students, it is 0.84%. The last LOT question type, namely correlation, is the same as the previous type of question, namely male and female students experience low understanding in solving questions regarding the correlation. More about the level of understanding can be seen in Table 3.

Table 3. Results of Students' Understanding of the LOT Questions Type

| LOT Questions Types | Male's Level of Understanding | Female's Level of Understanding |
|---|---|---|
| Classification | Low | Low |
| Serialized | Low | Low |
| Logical Multiplication | Less | Low |
| Compensation | Low | Low |
| Proportions | Low | Low |
| Probability | Low | Low |
| Correlation | Low | Low |

## Discussions

The results showed that classically, mathematics education students were still in the final concrete stage of 22.28%. This is of course contrary to Piaget's theory which states that subjects aged 11 years and over are already in the formal stage of thinking (Ibda, 2015; Mu'min, 2013). Mathematics education students who are the subjects of this study have the age of over 20 years, they should have been at a formal stage that allows them to have the ability to solve problems using their reasoning.

If these students still have concrete thinking patterns, it is feared that these students' thinking processes will have an impact on learning outcomes during their studies. So that the continuous impact is the delay in the undergraduate study period to more than 4 years. The results of this study inspire further research regarding the relationship between one's cognitive development and aspects of their study period in completing lectures.

Cognitive development in terms of gender also gives different results which can be seen in Figure 2. For the initial concrete stage, the final concrete and initial formal are dominated by female students. Meanwhile, the final formal stage was dominated by male students. This result is caused by several factors, one of which is because the subject of this study is dominated by a female.

The search is continued by looking at the work of students who are at each stage of cognitive development. For the initial concrete stage, the final concrete stage and the initial formal stage, more female students were able to answer questions correctly on the types of questions of classification, serialization, logical multiplication, and compensation. This is in line with research conducted by (Leongson & Limjap, 2003). While male students who are in the final formal stage, mostly answer LOT questions correctly and correctly on the types of classification, proportion, probability, and correlation questions.

This study shows that only 32.35% of students are in the initial and final formal stages. Students who are at this formal stage can think in a more abstract, idealistic, and logical way. The abstract quality of formal operational thinking is seen in verbal problem solving (Santrock, 2011).

After tracing the students' work who have the final formal stage of development, it shows that the student can do all the LOT questions well and shows that he has a high GPA. Meanwhile, other

students who have initial concrete, final concrete, and initial formal stages of development tend to complete LOT questions without reaching the result or only halfway.

When viewed from each type of LOT question in Figure 3, male students are more able to do well on questions of serialization, logical multiplication, compensation, proportion, probability, and correlation than females. Meanwhile, female students were able to solve classification type problems better than males. This is also in line with research (Orton, 1992), which states that there are differences in mathematics learning outcomes in terms of gender. Male will get a higher score than females.

The first classification question type asks students to sort whole numbers, fractional numbers from the smallest to the largest or vice versa. The results of student work showed that female students were able to rank well compared to the males who were less thorough in answering questions. This is less accurate because what is asked in the question is to sort the numbers from the largest to the smallest, but the answer is the opposite. This is in line with research conducted by (Maccoby & Jacklyn, 1974) that females will be superior in accuracy, thoroughness, accuracy, and thoroughness of thought.

The second LOT question type, namely serialization, shows that male students are superior in answering this question to female students. What is being asked in this question is the pattern of the n-th number. Most of the female students immediately used the arithmetic sequence formulas they had learned, but only half did not arrive at the result. Meanwhile, males tend not to use arithmetic sequence formulas, but they immediately answer using their logical reasoning. This is in line with research conducted by (Aini, 2017) which revealed that male students were more likely to use formal and logical thinking in solving math problems.

The third LOT question type, namely logical multiplication, was also dominated by male students who answered rightly and correctly. This question is about story problems in everyday life related to multiplication. The results of the work show that male students can answer this type of logical multiplication question well because they are already good at calculating the multiplication and division of numbers. Female students are also able to solve this problem, but because of their mistakes, they get the results of multiplication or division incorrectly.

The fourth LOT question type is compensation, where students are asked to determine the equivalent fraction and determine the angle of the triangle. Based on the results of student work, students were confused by the word equivalent which they had not heard before. As a result, some female students did not answer this question compared to the male students. In addition, the problem regarding the angles of a triangle cannot be solved by female students because they cannot imagine which angles are given. This clearly shows that the thinking of female students in this study is still very concrete, so they dominate the stage of concrete cognitive development. According to Suparno (2001), subjects who have cognitive development cannot abstractly imagine an object. This subject must see an object using his five senses.

The fifth LOT question type is the proportion or colloquially about the comparison. The results of student work tend to write what is given, asked but do not give an answer. In this type of question, the percentage of male students of

1.88% can solve this type of question, and a percentage of 1.49% of female students can solve this problem.

The next LOT question type is probability or theory about probability. The question is asked about the probability of drawing a card from a deck of bridge cards and the probability of drawing a marble in a collection of marbles. The average score of male and female students is almost the same for this type of question, namely 0.8% and the type of probability question is the type of question with the lowest percentage among other LOT question types.

The results of student work in this question type indicate that most of the students did not answer this question and did not write down informative things about this question. Students experience confusion in solving probability problems because they did not remember the formula or general form of the probability of an event, namely $\frac{(A)}{n(S)}$. In addition, students are confused about determining the sample space of an experiment. This is alleged because, during the time of learning in high school, these students were not given a good conceptual understanding in understanding the concept of probability (Laja, 2020).

The last LOT question type is Correlation. What is measured in this questions type is that students can make a relation between two variables. The first relation is between the trade-in value of the car and the age of the car, and the second is the relation between human height and age. In this type, male students occupy the highest percentage compared to female students with a percentage of 1.64% compared to female students who are only 1.37%.

One of the student works that attracted attention in this study was that there were male students who answered this question not only by giving answers in the form of relation but by providing examples and explanations. It can be seen from the work of this student that he is good at writing words in this case or it can be seen that this student is good at language as one of the competencies that teachers need to have, namely social competence related to the ability of prospective teacher students to communicate both orally and in writing (Pratama & Lestari, 2020). In addition, the results of this study support the theory which suggests that males have spatial abilities in solving mathematical problems by making completion diagrams or examples of solutions as alternative answers (Haralambos & Holborn, 2004).

In the end, this study shows that there are clear differences in cognitive development between males and females. Males over the age of 11 are more likely to have a better formal stage than females. This is supported by the theory that suggests that males will give better performance because they have a better level of intelligence than females (Hardianti, 2018; MZ, 2013). The results of this study refute research conducted by (Nafi'an, 2011) and (K. N. Aini, 2017). He further said that men are indeed superior in reasoning so they will tend to think formally.

Male students who tend to be in the final formal stage can answer all the questions given with a high level of understanding. It can be concluded that students who have a low stage of cognitive development, have a low level of understanding of the ability to think logically and vice versa. Students who have a high understanding tend to be able to solve problems that require varied logical processing abilities, which are not possessed at the previous level of cognitive development. This is in line with research conducted by (Asmaningtias, 2009; Santosa, 2013).

This study confirms that Piaget's theory of cognitive development which states that ages 11 years and over are in the formal stage can not be confirmed with the results of this study. The solution that can be given is to train these students to think logically in solving math problems. In addition, as a form of preventive activity so that the cognitive development stage is following the theory, it is recommended for teachers to pay attention to learning steps that pay attention to the cognitive development of their students.

One solution that can be applied is to use a learning syntax that affects one's cognitive development as in the research conducted by (Widada, 2016). The learning syntax based on cognitive development in this research in the core activities begins with the problem-giving phase according to the student's scheme, the thinking phase, the pairing phase, the exploration phase and the discussion phase of the exploration results and the core activity is closed with the conclusion phase. Learning syntax based on cognitive development aims to stabilize the cognitive structure that exists in students so that this structure becomes clear and orderly. Conversely, if this cognitive structure is unstable and disorganized, then the cognitive structure will tend to hinder the learning and teaching process.

## CONCLUSIONS

Based on the results of research and discussion, it can be concluded that the results of mapping the stages of cognitive development for females are 19.18% in the initial concrete stage, 36.99% in the final concrete stage, 13.70% in the initial formal stage and 1.37% in the final formal stage. While the results of mapping the stages of cognitive development for males were 9.59% in the initial concrete stage, 6.85% in the final concrete stage, 9.59% in the initial formal stage and 2.74% in the final formal stage.

Seeing the results of the cognitive development of mathematics education students who are still in the concrete thinking stage, further research will focus on the solutions provided so that their development goes up to the formal stage according to the existing theory through the development of teaching materials or learning media that can support their cognitive development. Departing from the results of this study, further research can be carried out by looking at the influence between the stage of cognitive development of the student and the period of study the student completes his lectures in the same department or a different department.

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