**Analysis of students’ creativity in direct proof of numbers theory)**

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***Abstract:*** The way of thinking logically and reasoning in number theory courses can be seen by the number of proofs of the properties of numbers in some basic set of numbers. This qualitative research aims to analyze student creativity in solving proving questions directly. The research involved 37 third semester students taking lectures on number theory. Data collection techniques provide questions then students with their own desires go to work in front of the class. Data analysis was performed by analyzing the creativity of the evidence carried out by students fulfilling which aspects of the aspects of creative thinking behavior and indicators of creative thinking abilities based on Mahmudi. A total of four students have been able to use the proving tools provided. The four students are creative because they meet at least one indicator of the ability to think creatively based on Mahmudi, student creativity in proving only 10.1% of the total number of students involved in this study. This can be seen from the one given problem which can only emerge four evidentiating creatives from the ten existing evidences. Thus, the class is included in the creative class. In addition, it is analyzed based on the number of students who are creative, more creative where in the class, male or female students. The results of research on this matter are more creative female students male students.*.*

***Keywords****:* Creativity, number theory, proof

**Abstrak:** Cara berpikir logis dan penalaran dalam mata kuliah teori bilangan dapat dilihat dari banyaknya pembuktian sifat-sifat bilangan pada beberapa himpunan dasar bilangan. Penelitian kualitatif ini bertujuan untuk menganalisis kreativitas siswa dalam menyelesaikan soal pembuktian secara langsung. Penelitian ini melibatkan 37 mahasiswa semester tiga yang mengambil kuliah teori bilangan. Teknik pengumpulan data memberikan pertanyaan kemudian siswa dengan keinginannya sendiri berangkat kerja di depan kelas. Analisis data dilakukan dengan menganalisis bukti kreativitas yang dilakukan siswa yang memenuhi aspek aspek perilaku berpikir kreatif dan indikator kemampuan berpikir kreatif menurut Mahmudi. Sebanyak empat siswa telah mampu menggunakan alat pembuktian yang disediakan. Keempat siswa tersebut kreatif karena memenuhi setidaknya satu indikator kemampuan berpikir kreatif berdasarkan Mahmudi, terbukti kreativitas siswa hanya 10,1% dari jumlah siswa yang terlibat dalam penelitian ini. Hal ini terlihat dari satu permasalahan yang hanya muncul empat pembuktian kreatif dari sepuluh alat bukti yang ada. Dengan demikian, kelas tersebut termasuk dalam kelas kreatif. Selain itu, dianalisis berdasarkan jumlah siswa yang lebih kreatif dimana di kelasnya ada siswa laki-laki atau perempuan. Hasil penelitian tentang hal ini adalah siswa perempuan lebih kreatif.

**Kata kunci:** Kreativitas, teori bilangan, pembuktian

**INTRODUCTION**

Learning is an activity that involves various aspects such as teachers, and students if learning is in school, while lecturers and students if learning is in college and the learning situation. Learning has the characteristics of mental processes and the process of contrutivism in building knowledge. The components that support the implementation of learning in tertiary institutions are the quality of students' thinking, grading abilities, learning strategies used, supporting media, learning goals and objectives to be achieved. All of these components are related to one another, so the learning process can run optimally.

Mathematics is a process of reasoning, character formation and thinking patterns, the formation of objective, honest, systematic, critical and creative attitudes as well as supporting science in drawing conclusions (Wanti, Farlina, & Rahayu, 2017). However, based on (Hernadi, 2008), Mathematics as a science with deductive reasoning relies on logic in convincing the truth value of a statement. Intuition factors and inductive thinking patterns play a large role in the initial process of formulating a construct that is the initial conjecture in mathematics. The process of discovery in mathematics begins with the search for patterns and structures, examples of cases and other mathematical objects. From all the information collected, the process is then continued by building a coherence and then compiling a commissioner. After the conjecture can be proven true then it will become a theorem or nature. Based on the opinion above, it can be interpreted that mathematics has an important role in the formation of characters and patterns of thinking that are creative, systematic, and logical in drawing conclusions. Many mathematical problems that we need to solve creatively because one with the other problems will be different solutions even if viewed as a type, one of them is in proving the property or theorem.

The curriculum in the Mathematics Education study program does not always learn about calculation problems like in the previous school level. There are several courses in Mathematics Education study programs that study material that can be said to be abstract. Abstract here means what is learned requires students to think logically and logically. This is because there are many properties or theorems that need to be proven using logical proof. One of the subjects that requires logical and logical thinking is number theory.

Mathematical statements such as definitions, theorems, and other statements are generally in the form of logical sentences, which can be in the form of implications, biimplications, negations, or in the form of quorid sentences. Logical operators such as and, or, not or are also often contained in a mathematical statement. So proving the truth of a theorem is nothing but proving the truth of a logical sentence.

Proof is a series of logical arguments that (Arifin & Herman, 2018) explain the truth of a statement. Mathematics is the language of mathematicians, while proof is a method of conveying mathematical truth to others who also speak the same language. Mathematical proof is a set of statements that are recognized according to logical reasoning with or without using other properties that have been proven true. Based on research (Hernadi, 2008), there are several methods of proof in Mathematics. Direct proof is one method of proof. Direct proof is usually applied to prove theorems in the form of implications . Statements  are hypotheses that are used as known assumptions, while  is statements which the purpose of proof. Logically, direct verification is equivalent to proving true statements  which are known  to be true. Furthermore, the indirect proof method, which is where we prove the implication , then the proof using the contraposition of the implications, i.e. . This is because the statement  is equivalent to . The third proof method is empty proof. In the empty proof, if the hypothesis  on the implication is already false, the implication is always true whatever the truth value of . Furthermore, for example if you want to prove the implications , it can be shown that  is correct. Whatever the truth value is , the implication is always true. This verification is called trivial proof. Proof can also be done by contradiction. Proof by contradiction can be used to prove the implications . For example, known  and . These two assumptions will come to a contradiction, namely there are one or more statements that contradict what is known. Other evidences available are existential proofing, proof of singularity, proof by counter example, proof by mathematical induction, and two-way proof. In this research, it explain direct proof.

Mathematics learning at the university level focuses more on the inculcation of concepts. Embedding mathematical concepts sometimes requires proof to know the truth. In number theory, there are several properties of numbers that don't require proof because the truth is clear. There are also properties that only apply to one set of numbers but not to another set of numbers. As an illustration, the closed nature of the division if we look at the set of rational numbers, the property is valid, but if in the set of numbers, the closed nature of the division does not apply.

In the research conducted (Arfatin Nurrahmah, 2018), it was motivated by the number of mistakes made by students at the time of verification. The purpose of his research is only to analyze the ability of students in number theory. Furthermore, according to previous research from (Amidi, 2018), it is motivated by the importance of the ability to think creatively to support the development of students in participating in learning mathematics, especially Basic Mathematics. The purpose of this research (Amidi, 2018) is as a consideration in determining learning methods that are adapted to students' abilities.

On the other hand, the results obtained by the research (Arfatin Nurrahmah, 2018) conducted with the questions given stated that the majority of students still had difficulty in solving the evidentiary problem. The study noted that as many as 60% of the samples taken did not yet understand how to solve the evidentiary problem. In research (Arfatin Nurrahmah, 2018) only discusses the mathematical proof ability of the Number Theory course but has not touched on its creativity. Because the work done by students can be different but equally true. The results of the study (Abdul Karim, 2018) which served as the basis for this study were the presentation of the data obtained presented in the form of a pie chart. The results obtained from the study (Amidi, 2018) is that the creativity ability of students is divided into three, namely the lower initial ability, moderate initial ability, and high initial ability. The criteria are elaborated according to (Amidi, 2018) ie students who have lower initial ability do not have the ability to provide more than one relevant idea, but have correct and detailed answers, students who have moderate ability can arrange more than one idea, so that the results can be right, students who have high initial ability can provide answers in more than one way / variety, the calculation process is detailed and the results are correct, and start trying to answer the problem in their own way.

Based on research (Arfatin Nurrahmah, 2018), the analysis is only limited mathematical proof ability. Researchers think that the problem of proof that there are several kinds in proving the nature of numbers that exist in the Number Theory, namely direct and indirect proof. The idea arose by narrowing down the evidentiary problem that was solved directly. This study is a research based on a special case of research (Arfatin Nurrahmah, 2018), which was only a matter of general mathematical proof, narrowed down to direct verification. In research (Amidi, 2018) discusses student creativity in the Basic Mathematics course. This research is equally discussing indeed discusses creativity but in the Theory of Numbers course. Research according to (Amidi, 2018) uses aspects of creative thinking and according to indicators of creative thinking abilities. The aspects of creative thinking and indicators of creative thinking ability according to Munandar (2009) are also used as a basis for data analysis in this study. However, data collection did not use written tests on research subjects. This study uses a quiz test that requires students to come forward in front of the class and directly work, then after the interview is submitted directly about their work. Actually, studies about creativity analysis have been investigated, for example study by (Purwanto, 2016), (Danggo, 2016), (Fardah, 2012), (Noorjannah, 2016).

Research topics - studies that previously only examined the mathematical proof ability of students but the material is the same as number theory. While the other previous research is examining students' creative thinking skills but the subject is Basic Mathematics. Thus, the researchers took the initiative to examine students 'creative thinking skills when proving directly on the Number Theory course with different data collection, namely giving students the opportunity to advance in front of the class writing answers and answering lecturers' questions about the origin of their steps (interviews).

In other words, in this study that is different, only discussed the creativity of students to solve the problem of proving the number theory by narrowing it using only direct proof. Proof was directly chosen by researchers because the observation of researchers to students who turned out to do a lot of proof has not collapsed. Students sometimes jump around proving and just memorizing. In the matter of certain properties that exist in this number theory, there have been students who can prove the nature but in a different way from what the lecturer teaches. So the idea arises to examine how many students who are creative bring up new ideas of proof and then classify the class creatively or not based on the amount of proof of creativity produced by students with the total amount of evidence that has been done by researchers. In addition, it is analyzed based on the number of students who are creative, more creative where in the class, male or female students.

**RESEARCH METHOD**

This research was conducted at Mathematics Education study program students at PGRI Adi Buana University Surabaya for number theory courses taught in semester 3 of the 2019/2020 school year. This research was conducted for two months from September to October 2019. The research subjects used in this study were 37 students.

The research method used in this study is a qualitative research method. According to (Amidi, 2018) knowing the ability of students to think creatively can provide alternatives in determining the right learning. In this study, the focus under study is student creativity in solving proof of number theory problems directly.

Broadly speaking, the steps undertaken in this study are first, providing tests of specific number theory questions. The questions given are only one question. The problem is that students are asked to prove the statement where the numbers are counting. The problem has been measured by the researcher about the possibility of several different evidences. In this problem, the researcher found ten different types of evidence. Students are asked to work in front of the class, not in writing, which is entered as a quiz score. So students really do the problem themselves. The method was chosen by the researcher because it was to find out which students were truly creative or not. If the questions are given then students are asked to work in writing, it is feared that there will be cheating on each other. As a result, the assessment of a class is a creative class will be less valid. This method also allows researchers to find out how many kinds of student creativity are in the class. After students work in front of the class, the researcher interviews students who can solve the given problem. The question during the interview asks which part makes the evidence different, asking also if there is an oddity of the proof step. Proof of the problem is stated true, if every step taken is accompanied by logical reasons and achieve the objectives of proof. The purpose of this direct verification is that the students work from what is known, namely where the enumeration number toward the final destination of proof must be the same as namely where the enumeration number is. The problem is an open ended problem, according to Becker and Shimada, which is a question that has a variety of answers. Because according to Getzles and Jackson suggests one way to measure the ability of mathematical creative thinking that is with open ended problems. Then, researchers identify aspects of students' creative thinking behavior based on the work. The aspects of creative thinking behavior and indicators of mathematical creative thinking ability according to Mahmudi (2009) are as follows:

**Table 1. Aspect of Creative Thinking**

|  |  |  |
| --- | --- | --- |
| No | Aspect of Creative Thinking | Description |
|  | Smothness | * Ability to solve problems and provide many answers to these problems.
* Ability to provide many examples or statements related to certain mathematical concepts or situations.
 |
|  | Flexibility | * Ability to use a variety of problem solving strategies.
* Ability to provide various examples or statements related to certain mathematical concepts or situations.
 |
|  | Novelty | * The ability to use strategies that are new, unique, or unusual to solve problems.
* The ability to give examples or statements that are new, unique, or unusual.
 |
|  | Detail | Ability to explain in detail, coherently, and coherently with mathematical procedures, answers, or certain mathematical situations. |

The thing stated Mahmudi (2009) is in line with what was stated Buchari(2013), that there are five characteristics that characterize the ability to think creatively, namely fluency, flexibility, authenticity, decomposition, and reformulation. Fluency is the ability to generate many ideas. Flexibility is the ability to express various kinds of solutions or approaches to problems. Authenticity is the ability to come up with ideas in original ways, not cliches. Decomposition is the ability to describe in detail. Re-formulation is the ability to review an issue based on a perspective that is different from what people already know.

According to Slameto, the characteristics of creativity can be divided into two, namely cognitive and non-cognitive characteristics. The cognitive features of creativity consist of originality, flexibility, and fluency. Non-cognitive characteristics of creativity include motivation, personality, and creative attitude. Good creativity includes cognitive and non cognitive characteristics, which are potentials that need to be instilled and developed.

Data collection techniques in this study used triangulation. Triangulation is defined as a data collection technique that combines various existing data collection techniques and sources. Data collection techniques used in this study used triangulation which was conducted by comparing data on the results of the problem solving theory given by interviewing the results of tests written by students in front of the class.

The analysis technique of student creativity in direct verification is to check whether the student's work uses direct verification. If yes, continue by adjusting the problem solving techniques used with the indicators used by the foundation. Questions and answers to student quizzes on number theory courses are examined not to see whether the student's work is correct or not, but in terms of the creativity of the work that is different from other evidences. To find out the creativity really exists in the work of students, the lecturer asks them to advance in class and explain the results of their work. So the students interviewed are students who progress in working in front of the class. This interview aims to clarify and then analyze the results of problem solving by students in a qualitative descriptive manner. If a student's work meets one of the indicators on which the foundation is based, the student is declared creative. Furthermore, the creative students are grouped according to gender.

**HASIL DAN PEMBAHASAN**

The description of the analysis of the questions given is inseparable from the characteristics of the respondents as explained by (Abdul Karim, 2018). Characteristics of respondents can be seen from gender. Overall, a description of the characteristics of student respondents can be seen in diagram 1.

Diagram 1 shows that the number of female respondents dominated by 32 people or 86 percent, while only a small proportion of respondents who were male were 5 people or 14 percent.

Analysis of the questions given by the lecturer was also chosen based on the level of possibility of respondents to explore their creativity. Other possible proofs can be found in accordance with the ability of 3rd semester Mathematics Education students.

The questions given to students by the lecturer are a matter of number theory about the number multiplication operations. The questions chosen are already taken into account by lecturers which can be proven in several ways. The test question is only one question, which is where the chopped number.

After giving a number theory test, students answer one question given by working in front of the class. From what students do, the lecturer gives several questions about what students have done. This method is taken because researchers want to really know which creative students explore their original ideas in proving or just copying their friends' work.

Analysis of student creativity can be seen through the ability to give unusual answers, others from others, which are rarely given by people or think original. Based on these indicators can be seen in diagram 2.

In the research method conducted by researchers, there are 4 out of 37 students who dare to advance and show the results of their creativity. There are 4 students who give their proof of ideas that are different from the evidence given by the lecturer. Analysis of creativity in the number theory courses presented in Diagram 2, the percentage of the level of creativity in direct proof shows 11% of students who are creative and dare to show it in front of the class. As many as 89% of the study sample has not shown creativity. Researchers conducted interviews with several students who did not come to the front of the class to answer. Based on the results of interviews with some students who did not advance in front of the class, because some of the students considered lectures on number theory to be a difficult subject, 1) material given in number theory courses, abstract in nature so difficult to understand 2) had many theorems and the nature of the proof of concept must be understood, 3) It is difficult to find other evidence with what is given by the lecturer, 4) What is proven by students who are not advanced, almost the same as what has been proven by advanced students.

Furthermore, the analysis of student creativity in direct proof based on sex is seen from the suitability in the courage to go forward and answer the questions can be seen in diagram 3

Analysis of creativity based on sex as presented in Diagram 3, the percentage of the level of creativity of direct evidence of male students is only 3 percent or only 1 respondent, and men who have not shown creativity are as much as 11 percent or 4 respondents. While the percentage of female students who showed creativity was 8 percent or 3 respondents, and the percentage of female students who did not show their creativity was 78 percent or 29 people. Based on these data it can be concluded that there are fewer male students who show creativity than female students. However, when viewed from his presentation, male students as much as 20% of the number of men in the class showed their creativity. While female students only 9% of the total number of female students.

In the proof shown by students in front of the class, it is not 100 percent immediately correct in every step, there are some that need improvement after the lecturer checks it. In checking, the lecturer can explore the creativity of the evidence and the validity of the student's proof through interviews. However, what is seen in this study is the proof of creativity.

In this article, four direct evidences were shown by students through their work on the board,



**Figure 4. Creativity by student 1**

The interview that occurred with student 1 as follows:

*1.1 Lecturer: From your proof, which step do you think is different from the others?*

*1.2. Student 1: In the second step Ma'am, I used the associative nature.*

*1.3. Lecturer: In the third step, is it in accordance with the provisions?*

*1.4. Student 1: It seems like Ma'am. I try to be in front.*

*1.5. Lecturer: Your aim is correct, but check again.*

*1.6. Student 1: Oh yes ma'am. I skipped a few steps.*

*1.7. Lecturer: The next step, why is it chosen like that?*

*1.8. Student 1: I try to be close to.*

*1.9. Lecturer: Why are the steps like that?*

*1.10. Student 1: Because the ultimate purpose of the proof, Ma'am*.

In Student 1's answer, student creativity in proving is done by using the definition of multiplication then the associative nature in the next step. By changing the parentheses that indicate which numbers are operated first using the associative nature, so that in the next step will provide a different proof. When seen, the students' answers on the blackboard that gave rise to the proof of creativity are as follows:



Student answers are not 100 percent correct because there are several steps of proof that were passed. However, in this study, what was seen was the creativity of the idea of the emergence of proof.

Based on the results of interviews and technical analysis used by student 1, it can be concluded that student 1 fulfills the novelty aspect because it matches Student 1's answer in conversation answer number 1.2. However, there are other indicators that are not met by student 1 is thinking in detail, because it does not explain the details of the steps. Many steps on proof are skipped, not written down in detail. This can be seen from the answer to step 3 and the results of interview number 1.6. In conclusion, Student 1 has included mathematical creative thinking because it at least fulfills one aspect of creative thinking.



**Figure 5. Creativity of Student 2**

The interview that took place with Student 2 was as follows:

*2.1. Lecturer: From your proof, which step do you think is different from the others?*

*2.2. Student 2: In the second step Ma'am, I used the commutative nature.*

*2.3. Lecturer: Why was that step chosen?*

*2.4. Student 2: The number I want to put in the front.*

*2.5. Lecturer: Next step 4, is it correct? Try checking again!*

*2.6. Student 2: \* paused.*

*2.7. Lecturer: That is a step that has been missed.*

*2.8. Student 2: Oh yes, ma'am.*

In Student 2's answer, student creativity in proving is done by using the definition of multiplication and then the commutative property in the next step. When seen, the students' answers on the blackboard that gave rise to the proof of creativity are as follows:



Student Answer 2 in the first step, already put the numbers in front because the final purpose of the proof is the next proof step which is different from what the lecturer has given. Direct proof given by Student 2 shows that the student has been able to identify the steps that should be taken to go to the final destination of proof and minimize the proving that is getting longer because it is inappropriate to take steps.

 Based on the results of interviews and technical analysis used by student 2, it can be concluded that student 2 meets the novelty aspect because it can use a new strategy. However, there are other indicators that are not met by student 2 is thinking in detail, because it does not explain the details of the steps. Many steps on proof passed. This can be seen from the third step to the fourth step. In conclusion, Student 2 is already thinking creatively.



**Figure 6. Creativity of student 3**

The interview that took place with Student 3 was as follows:

*3.1. Lecturer: From your proof, which step do you think is different from the others?*

*3.2. Student 3: In the first step Ma'am, I used the previously proven nature.*

*3.3. Lecturer: From the first step to the second, is it correct?*

*3.4. Student 3: Yes, ma'am.*

*3.5 Lecturer: How many numbers should be associated?*

*3.6. Student 3: Three numbers.*

*3.7. Lecturer: If so, which ones are associated?*

*3.8. Student 3: *

*3.9. Lecturer: The first step, have you grouped these three numbers?*

*3.10. Student 3: Not yet, Ma'am.*

*3.11. Lecturer: Try to describe in detail until you get a second step statement!*

*3.12. Student 3: Fine, ma'am.*

*3.13. Lecturer: Likewise the third step to the fourth, is corrected.*

*3.14. Student 3: Okay ma'am*

In Student 3's answer, student's creativity in proving is done by using the numeric nature that has been proven before, that is.

Student Answer 3 in the first step, has not placed the numbers in front. When compared to the proof done by Student 2, the step in Student 3 is not straightforward to the final destination of proof which should place the number in front. However, the advantages of Proof Student 3, can already use the existing number of census numbers that have been proven valid and have been proven by previous lecturers.

Based on the results of interviews and technical analysis used by student 3, it can be concluded that Student 3 fulfills the novelty aspect because it uses strategies that are rarely used. Aspects of fluency are also fulfilled because of the ability to find solutions to certain problems with certain strategies. In addition, student 3 also fulfills another indicator in creative thinking, namely the flexibility aspect. This is because Student 3 can provide a variety of problem solving strategies that are used. The direct use of the property  can cut the step that should be longer when we only use the definition of multiplication given. As a result, the step of proof of Student 3 is shorter than when proven by using the definition of multiplication. However, there are other indicators that are not met by student 3 is thinking in detail, because it does not explain the details of the steps. Many steps on proof passed. This can be seen from the third step to the fourth step. In conclusion, Student 3 fulfills aspects of fluency, flexibility, and novelty. So Student 3 who thinks creatively.



**Figure 7. Creativity of Student 4**

The interview that took place with Student 2 was as follows:

*4.1. Lecturer: From your proof, which step do you think is different from the others?*

*4.2. Student 4: In the second step Ma'am, I used the associative nature but it was different from the previous proof.*

*4.3. Lecturer: Why was that step chosen?*

*4.4. Student 4: To be different from the previous evidence.*

*4.5. Lecturer: About the first step taken like that, could other alternative proof be taken.*

*4.6. Student 4: You can, Ma'am.*

*4.7. Lecturer: At what step?*

*4.8. Student 4: In step five, ma'am.*

*4.9. Lecturer: What is the next step?*

*4.10. Student 4: Move close to through the associative and commutative property*

In Student 4's answer, student creativity in proving is done by using an associative property, but different from Student 1. Student's Answer 4 in the first step, arguably much longer than the previous student's proof.

Based on the results of interviews and technical analysis used by student 4, it can be concluded that Student 4 thinks flexible because it can change the way or strategy. In addition, Student 4 also fulfills another indicator in creative thinking, namely thinking novelty. This is because student 2 can produce answers other than those given by lecturers and other students. The aspect of fluency was also fulfilled because it produced many answers to the problem of proof. Another indicator that is also fulfilled by student 4 is the aspect of detail, because it explains the details of the steps. Each step is explained along with the reasons, although it causes the steps to look longer than the others. In conclusion, 4th student has creative thinking and fulfills most aspects of creative thinking from other research subjects.

Overall, only 4 research subjects indicated creative thinking with 4 different proofs. However, there are actually 10 evidences for open questions. The conclusion is that the class is a creative class, because more than 25% of the total evidence can be explained by students in the class.

However, if you look back at Diagram 1, it can be concluded that the number of students showing creativity in direct proof of the Numbers Theory problem is still not optimal. Most students are still unable to explore their creativity in proving a given number of the numeric properties. This may be caused by many students who have not been trained to prove and memorize the proof of property given by the lecturer alone.

**SIMPULAN DAN SARAN**

Broadly speaking, in this study it can be concluded that the amount of student creativity in proving only 40% of the total number that exists. This can be seen from the one problem given by the lecturer, only four creative evidences can emerge. Even though there are 10 different evidences. However, the class as the subject of this study is a creative class.

Students really need to be encouraged to carry out proof with their own ideas so that they don't merely memorize the evidence. Female students are more thorough when they prove that each step is more coherent with their reasons. Female students are more creative than male students.

 Some students have been able to use the proving tools provided by lecturers, in this study, the proving tools given to students to prove are the definition of multiplication, the commutative property of multiplication, associative multiplication, and the property of the number of numbers .

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