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An Approximation to the Knowledge of the Proportionality of the Students and Teachers of Primary Education in Balearic Islands (Spain)

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Abstract

This paper addresses the worrying lack of training in proportionality among teachers and future teachers of Primary Education. A review of the literature and the realization of a survey, a lack of knowledge and skills on the subject of proportionality is evidenced. This lack of training can have negative consequences in the learning of Primary Education students, who do not receive an adequate education in proportionality. The conclusions highlight the need to promote good teacher training in proportionality, since the vast majority of teachers and future teachers are limited to using decontextualized methods without knowing how to identify magnitudes or situations of proportionality. This study highlights the need to promote awareness and importance of proportionality in the primary mathematics curriculum, and emphasizes the importance of improving teacher training to address the lack of knowledge in proportionality among primary school teachers and future teachers.

Keywords: *Proportionality, Teacher training, Proportional reasoning and rule of three*

1. Introduction

According to Sierra and Gascón (2011), there is a lack of research on fractions and proportional reasoning. We can still find doctoral theses such as the one by Martínez-Juste *et al.* (2022) on the analysis of proportionality in the first cycle of primary education, but even so, there is very little research on this topic.

Nowadays, constructivism, which according to Trenas (2009), is a concept that refers to the idea that individuals create ideas about how the world works and pedagogically construct their own learning, has a very important role in education, since teaching is focused on students' learning, which is active and which constructs its own learning (Lopera Zapata, 2014).

According to Valiente *et al.* (2001), in order to teach mathematics, there must be a coherent and organized structure of the contents in order to propose strategies that allow solving problems from different points of view. Importance must be given to cognitive processes, promoting motivation and taking into account the needs and individual characteristics of each student.According to Valiente *et al.* (2001), in order to teach mathematics, there must be a coherent and organized structure of the contents in order to propose strategies that allow solving problems from different points of view.

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Importance must be given to cognitive processes, promoting motivation and taking into account the needs and individual characteristics of each student.

According to Godino *etal.* (2003), one of the objectives of education is to form educated citizens, and Mathematics Education also aims to teach this culture. We do not want to turn students into "amateur mathematicians", nor do we want them to know how to do complex calculations, since today we already have the necessary technologies to solve this type of questions. We want students to be able to interpret and critically evaluate mathematical concepts and to be competent to solve mathematical problems that may arise in their daily lives.

According to Rendón Gonzalez (2018):

> All the concepts that make up proportionality are acquired through practice and contact between school and community by transferring the knowledge acquired in the classroom to the contextual field of daily work. Therefore, proportionality can be considered as a mathematical notion that has a wide field of action, which is extremely important, since from the subsequent disciplinary field, it transcends in different subjects such as: geometry, trigonometry, functions, among others; allowing the student to have a greater applicability of the concept throughout his academic life.

Proportionality is the relationship that exists between two magnitudes. From this, proportional reasoning has a very important role since it is necessary to understand physical phenomena, economic situations and everyday life, for this we must use the concepts of reason and proportion (Oller Marcén and Gairín Sallán, 2013). In different everyday situations you can find proportionality when increasing a recipe and for how many people you want your elaboration to be, the time it takes to go to a place with the speed, to calculate the grade of an exam, etc.

In order to achieve a development of students' knowledge, proportionality must be taught in an organized and structured way, it is necessary to put in order and structure the concepts and knowledge, giving it a sense and that it can be applied in the context in which it is being worked, so that the student understands the concepts that are part of proportionality (Rendón Gonzalez, 2018).

Several studies mentioned in Balderas *et al.* (2014), explain that there are difficulties in solving proportionality problems, and conclude that poor development of proportional reasoning and poor teaching may be the reason for this.

Karplus *et al.* (1983) define proportional reasoning as a term that denotes reasoning in a system of two variables between which there is a linear functional relationship and leads to conclusions about a situation or phenomenon that is characterized by a constant proportion.

On the other hand, Lamon (2007 - Cited in Valverde and Castro, 2009) proposes that proportional reasoning means being able to give arguments that support statements made about the structural relationship between four quantities (a, b, c, d) in a context that simultaneously involves covariance of quantities and invariance of ratios or products. In other words, Valverde Soto and Castro Martínez (2009) explain that "*this could consist of the ability to distinguish a multiplicative relationship between two quantities, as well as the ability to extend the same relationship to other pairs of quantities*".

Cramer, Post, and Currier (1993 - Cited in Modestou and Gagatsis, 2010) explain that reasoning is considered synonymous with the ability of people to solve proportional missing value problems .

Oller Marcén and Gairín Sallán (2013), add that "Proportional reasoning is a resource that has been used to solve problems that we could call every day since time immemorial". That is, we use proportional reasoning on a daily basis to solve aspects of everyday life. Moreover, according to Rendón (2018), there are many problems of everyday life that can be solved by means of proportionality.

Rivas *et al.* (2012) observe the teaching of proportionality as:

> A complex task, which requires the teacher to go beyond the simple application of rules, and to reason proportionally, as well as to initiate a work agenda aimed at achieving the development of proportional reasoning in their students (p. 563).

That is, it is not enough for the teacher to teach a simple rule that works to solve proportionality problems, the teacher has to go further and get his students to develop good proportional reasoning.

Designing the educational curriculum is important, taking into account the characteristics of development and the difficulty of the questions, for example, using the revised Bloom's taxonomy in subjects such as science and mathematics (Pizà-Mir, 2022a).

Lamon (2005 - Cited in Buforn and Fernandez, 2014) points out that "proportional reasoning is multifaceted and integrates different components: the meanings of mathematical objects (interpretations of rational number) and the ways of reasoning with these meanings (relational thinking, covariance, *up and down* reasoning, *unitizing*)" .

According to Mayo *et al.* (2013) in the knowledge society in which we live, the role of the teacher is not that of a mere transmitter of knowledge and wisdom, since nowadays, future teachers are trained in an environment full of stimuli, so they should be trained through thinking and the development of attitudes.

The training of future teachers must provide the necessary knowledge, skills and abilities so that they can correctly carry out their work as teachers in any situation that may arise (Mayo *et al.*, 2013; Pizà-Mir and Suñé-Vela, 2022). In other words, every teacher has to have a good training to be able to cover all the needs of their students and to be able to transmit their knowledge in a correct way so that their students achieve meaningful learning (Pizà-Mir, 2022b).

Research has revealed that many Primary and Secondary Education teachers have several difficulties with the idea of proportionality, also, they have a lack of understanding in the way in which proportional reasoning is developed. This factor causes some teachers to use routine procedures such as the rule of three for their students to learn to solve proportionality situations (Harel and Behr, 1995 cited in Buforn and Fernandez, 2014). In other words, teachers are not well trained, so they find it difficult to teach their students correctly and resort to the use of rules.

Therefore, the aims of this work are as follows:

1) To analyze the level of knowledge about proportionality possessed by Primary Education teachers. This objective will make it possible to evaluate the training and preparation of the professionals in charge of teaching this fundamental concept in the educational curriculum.
2) To evaluate the level of knowledge about proportionality among students in the Primary Education level. This objective seeks to determine whether future teachers have a solid understanding of this topic and whether they are adequately prepared to teach it to their future students.
3) To identify possible difficulties or misconceptions that both teachers and student teachers may have in relation to proportionality. This objective seeks to detect problem areas or common misunderstandings that may influence the teaching and learning of this concept.

2. Methodology

In order to analyze the knowledge of proportionality, an *ad hoc* survey has been made to people who are studying or have studied Primary Education, in which the variables are quantitative.

In addition, the paradigm is positivist, since it is a quantitative study that aims to explain and predict the lack of training of teachers and future teachers of Primary Education and a questionnaire was used to collect the information.

2.1. Instrument

To carry out this research, an *ad hoc* survey was carried out using *Google Forms.* The questionnaire is self-made, anonymous to guarantee the sincerity of the answer and consists of 24 questions, 4 of them to identify the type of individual who performs it, 14 of a theoretical nature and 6 of a practical nature. Most of these questions are true/false or multiple choice, but there are also free-response questions.

This questionnaire is self-administered, as it is provided directly to the participants with clear instructions. It has also been disseminated through social networks.

The questionnaire was chosen as the data collection instrument, since for this quantitative study we wanted to reach as many people as possible.

To carry out the statistical analysis, Excel was used to extract the percentages according to whether they were male or female and whether they were undergraduate students or primary school teachers for each question.

2.2. Sample

The sample of this research is probabilistic, since it is formed by a subgroup of the population, in this case, people who have completed the degree of Primary Education. All participants have had the same possibilities of participating in this study.

A total of 20 male and 28 female elementary school teachers and 42 female and 9 male elementary school students participated, for a total of 100 respondents.

The sample is not large enough to distinguish by experience in the case of teachers and by course in the case of students.

2.3. Description of the Questionnaire

As can be seen in Table 1, most of the theoretical questions are about the use of rules for solving proportionality problems both in daily life and in schools, since we want to find out what percentage of teachers or future teachers limit

Table 1: Survey Questions, Their Intention and, if Applicable, the Author on Which They are Based

Question	Statement	Intention	Author
1, 2, 3, 4	1. Sex 2. Are you an elementary school teacher or an elementary school student? In the case of teaching at different levels/courses, please choose the option with the highest teaching load. 3. If you are a teacher, how many years have you been teaching? 4. If you are a Primary Education student, what grade are you in?	These questions are intended to obtain more specific information about individuals.	None
5, 6, 7, 8, 12, 13, 16, 18, 19	5. Do you use the rule of three to solve proportionality situations in everyday situations outside of school? 6. Do you (or would you) use the rule of three to solve proportionality situations in your classes? If you are still a student, would you use the rule of three with your students? 7. Do you know any other method to solve proportionality situations? Which one? 8. If yes, if you know of others, do you (or would you) use them in class? 12. A ratio is an equality between proportions. 13. Proportionality is a longitudinal and transversal object of mathematics. 16. Proportional reasoning is a daily tool in our lives. 18. If by increasing one magnitude, the other also increases and by decreasing one, the other also decreases. It is a situation of... 19. Two magnitudes are directly proportional if by increasing one, the other decreases; and if by decreasing one, the other increases.	These are test questions to get a small measure of the theoretical knowledge of individuals.	5, 6, 8: Rivas, *et al.* (2012). 12: Mochón (2012) 13: Wilhelmi (2017) 16. Oller Marcén and Gairín Sallán (2013). 18 & 19: González Álvarez, Acevedo and Montoya García (2017) and Rendón González (2018)
9, 10, 11, 14, 15	9. Do you agree with the following statement: "knowledge of the rule of three helps to understand and explain the answers given by the students". 10. Do you consider that you have had sufficient/ adequate training in proportionality? 11. Do you agree with the following statement: it is better or easier to propose a method of solving proportion problems that allows solving all the exercises/problems that arise? 14.Do you think the rule of three should be included in the curriculum? 15. Why?	These questions allow us to know what opinion our individuals deserve in reference to the topic in question.	9 & 11: Rivas *et al.* (2012).
20, 21, 22, 23, 24	20. Of the following situations which ones represent proportional magnitudes. 21. Does the following statement represent a direct or inverse proportionality problem? 22. What is the reason for the following image? 23. Solve the following proportion. For two cakes 8 eggs are needed, how many cakes can be made with 20 eggs? 24 Which of the following tables expresses proportional quantities?	With these questions we intend to test the level of assimilation of content that our individuals have had in order to compare the results with the level of theoretical knowledge.	None

themselves to using the rule of three and what other methods are used. There are also some questions about direct and inverse proportionality of a theoretical nature that can then be checked with those of a practical nature, in this way we ensure that teachers know how to apply theory in practice. Finally, there are different questions of a practical nature to check if the participants of this study know how to identify a situation of proportionality since, as we have seen in the theoretical framework, it was one of the difficulties that the teachers had. All these questions are important to analyze the knowledge that teachers and future teachers in Primary Education have about proportionality, in this way it will be possible to know if teachers are prepared to teach this topic to their students.

3. Results and Discussion

3.1. Characteristics of Participants

In this survey, 29% of the participants are men and 71% are women. As can be observed there is a higher participation of women, since women may show a greater inclination towards fields such as psychology and education (Eccles, 1994; Su *et al.*, 2009).

In the case of men, 69% are primary education teachers and the remaining 31% are undergraduate students. On the other hand, in the case of women, 40% are teachers and the remaining 60% are undergraduate students.

A study on the experience of the participants could not be carried out since the sample is not significant.

The results on use of the rule of three, knowledge of other methods, teacher and undergraduate student training, and curriculum can be seen in Table 2.

Table 2: Percentage of Responses According to Category (Teachers And Students) and Gender to Questions About Their Opinion Regarding Proportionality

	Teachers				Undergraduate Students			
	Male (N=20)		Female (N=28)		Male (N=9)		Female (N=42)	
Question (Item)	Yes	No	Yes	No	Yes/	No	Yes	No
5	85%	15%	96%	4%	89%	11%	79%	11%
6	90%	10%	89%	11%	89%	11%	95%	5
7	55%*	45%	21%**	79%	11%***	89%	9%****	91
9	70%	30%	46%	54%	78%	22%	70%	30
10	25%	75%	39%	61%	56%	44%	28%	72
11	65%	35	82%	18	100%	0	88%	12
14	75%	25	61%	39	78%	22	77%	23

Note: *Reduction to unity and fractions; **Reduction to the unit and proportionality tables; ***Fractions; and ****Reduction to unity.

3.2. Use of the Rule of Three

85% of male teachers, 96% of female teachers, 89% of male students and 79% of female students use the rule of three to solve situations of proportionality in daily life. On the other hand, when it comes to using the rule of three in the classroom, this percentage is 90% for male teachers, 85% for female students, remains the same for male students and 89% for female teachers. It can be observed that the great majority of teachers and students use this method to solve proportionality situations. This information stands out, since it coincides with the research of Harel and Behr (1995) cited in Buforn and Fernandez (2014) in which the lack of teacher training was related to the use of routine procedures.

On the other hand, 70% of male teachers, 78% of male students and 70% of female students consider that the rule of three helps to explain and understand the answers given by the students, while this percentage decreases to 46% in the case of female teachers, coinciding with Rivas *et al.* (2012) in which they observed that the participants could not

correctly assess the answers provided by the students and concluded that using the rule of three could neither understand nor explain the students' answers.

Also, 100% of male students, 88% of female students, 65% of male teachers and 82% of female students prefer to use only one method of solving proportionality problems and as we have seen above this method is usually the rule of three. This percentage is higher in students than in teachers and these results coincide with those of the study by Rivas *et al.* (2012) in which the majority of future teachers consider that it is better to propose only one method of solving proportionality problems that allows solving all of them.

3.3 Knowledge of Other Methods

In addition, 91% of female students, 89% of male students and 79% of female teachers admit not knowing any other method. On the other hand, it is striking that 55% of male teachers know methods other than the rule of three, as this is a significant difference with respect to the rest of the respondents. The most repeated methods were reduction to unity and fractions.

3.4. Teacher and Undergraduate Student Training

In addition, 75% of male teachers, 61% of female teachers and 72% of female students consider that they have not had good training in proportionality, coinciding with the studies of Buforn and Fernandez (2014) in which he explains that future teachers have little knowledge in proportional reasoning and proportionality. On the other hand, only 44% of male students consider that they have not had good training, although the sample is too small to be significant.

3.5. Rule of Three in the Curriculum

Between 61% and 78% of the respondents consider that the rule of three should be contemplated in the curriculum for reasons such as it is easier or simpler, the vast majority of these previously answered that it was the only method they knew. Currently, with the LOMLOE Law (BOIB, 2022) the rule of three is not contemplated in the Primary Education curriculum of the Balearic Islands, on the other hand in the previous educational law LOMCE (BOIB, 2014), it was contemplated. The most repeated reasons why respondents consider that it should be included in the curriculum are: because it is simple or easy or because it is the only one they know.

The results on the concept of ratio and proportion, transversality of proportionality, proportional reasoning, direct and inverse proportionality and detection of proportional situations and magnitudes can be seen in Table 3.

Table 3: Percentage of Responses According to Category (Teachers and Students) and Gender to the Questions About Their Theoretical and Practical Knowledge of Proportionality

	Teachers				Undergraduate Students			
	Male (N=20)		Female (N=28)		Male (N=9)		Female (N=42)	
Question (Item)	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
12	45%	55%	25%	75%	33%	67%	21%	79%
13	75%	25%	75%	25%	89%	11%	81%	19%
16	90%	10%	93%	7%	78%	22%	86%	14%
17	90%	10%	93%	7%	100%	0%	84%	16%
18	95%	5%	89%	11%	78%	22%	79%	21%
19	35%	65%	21%	79%	22%	78%	23%	77%
20	70%	30%	75%	25%	89%	11%	74%	26%
21	20%	80%	43%	57%	22%	78%	44%	56%
22	100%	0%	93%	7%	89%	11%	93%	7%
23	35%	65%	43%	57%	11%	89%	14%	86%

3.6. Concept of Ratio and Proportion

As can be seen in Table 3, 55% of male teachers, 75% of female teachers, 67% of male students and 79% of female students believe that a ratio is an equality between proportions, this statement being false. Mochón (2012) explains that "a proportion is basically an equality of ratios. The high percentage of wrong answers stands out, being higher in women than in men. In addition, respondents have difficulties with the concept of ratio and proportion both in theory and in practice, since in question 21 they had to identify the ratio of a practical exercise in which only 20% of male teachers and 22% of male students answered correctly, this percentage doubles in the case of women with 43% for teachers and 44% for students, although it is still a fairly low percentage. This shows that the studies by Lo (2004) and Person *et al.* (2004) are right, teachers and future teachers have difficulties with the concepts of ratio and proportion, both to understand them and to teach and explain them. Moreover, according to González *et al.* (2017) all concepts related to proportionality are formed starting from practice and with direct contact between the school and the community. We will find ourselves in many occasions in daily life where the use of proportionality is needed.

3.7. Transversality of Proportionality

75% of male and female teachers, 89% of male students and 81% of female students consider that proportionality is a longitudinal and transversal object of mathematics coinciding with Wilhelmi (2017) who explains that proportionality is also worked in Art Education.

3.8. Proportional Reasoning

Between 78% and 93% of respondents think that proportional reasoning is a tool of our daily life, confirming what Oller and Gairín (2013) explain in their research: "*Proportional reasoning is a resource that has been used to solve problems that we could call every day since time immemorial*".

3.9. Direct and Inverse Proportionality

Writing in the survey the following statement "If by increasing one magnitude the other also increases and by decreasing one, the other also decreases", between 84% and 100% of the respondents consider that it would be in case of a situation of direct proportionality, this being true, as González *et al.* (2017) explains to us. On the other hand, writing "Two magnitudes are directly proportional if by increasing one, the other decreases; and if by decreasing one, the other increases.", between 78% and 95% of respondents were able to detect that the statement was false. In this case, we can see that the vast majority of respondents know how to differentiate between the concepts of direct and inverse proportionality. On the other hand, in practical question number 20, the percentage of correct answers is between 70% and 89%, which is slightly lower than in the theoretical questions. Also, it should be noted that when calculating a simple inverse proportionality problem, between 89% and 100% of the respondents answered correctly, these percentages being quite high. As we have been able to observe, both teachers and students have good training in direct and inverse proportionality.

3.10. Detection of Situations and Proportional Magnitudes

Finally, in question 19, in which it was necessary to detect which situations were proportional, only 35% of male teachers, 21% of female teachers, 22% of male students and 23% of female students chose the correct answer. The percentages were even lower in the case of students in question 23, in which proportional magnitudes had to be detected, and only 11% of men and 14% of women answered correctly. On the other hand, in the case of men, these percentages increase slightly, with 35% of men and 43% of women answering correctly. With these results we reaffirm the research of Modestou and Gagatsis (2010) and Fernández *et al.* (2010) in which it is shown that students for teachers and teachers do not know how to differentiate situations of proportionality from those that are not situations of proportionality.

We agree with Godino and Batanero (2002), who explain that it is essential for teachers to receive solid training in proportionality and its didactics. This implies developing a deep knowledge of the concepts and strategies of proportionality, as well as learning to design and carry out teaching situations that promote proportional reasoning.

Also, it is necessary to relate the teachings to aspects of everyday life in order to achieve meaningful learning. According to Modestou and Gagatsis (2010), it is important for teachers to approach proportionality in a meaningful and contextualized way. This implies relating proportionality concepts to real-world situations and allowing students to apply their knowledge.

- Some practical implications would be:
- Present proportionality situations that are relevant to students.
- Problems related to the purchase of food.
- Planning a trip
- Create recipes
- Use manipulatives, graphs, or visual representations to help students understand proportional relationships.
- Using building blocks to visually represent proportional parts.
- Bar, line or pie charts to show proportional quantities.
- Use proportion diagrams that show the parts in relation to the whole.
- Relate proportionality to other areas of the curriculum to show the applicability and usefulness of proportionality concepts in different contexts.
- In Art Education students can study how artists use proportions to create harmony and balance in their compositions.
- In geography students can measure proportionality on maps.

In addition, proportional reasoning should be encouraged. According to Rivas *et al.* (2012), teachers should focus on the development of proportional reasoning in their students. Some practical implications would be:

- Provide students with a variety of proportionality problems that require different solving strategies.
- Inverse and direct proportionality problems.
- Rule of three or reduction to unity.
- Bar diagram.
- Encourage class discussions where students can share and compare their solving strategies, and justify their answers using mathematical arguments.
- Invite students to share and compare their problem-solving strategies and compare them.
- Working in groups.
- Ask questions that stimulate critical thinking and proportional reasoning.
- "How do you know that these two quantities are proportional?"
- What would happen if we changed one of the values by this ratio?"

Finally, one must know how to provide good feedback. According to Buforn and Fernandez (2014), it is essential that teachers provide effective feedback to students during proportionality learning. This involves identifying and addressing specific difficulties students may have, offering clear explanations, and providing opportunities for practice and reinforcement. Feedback and educational research (Pizà-Mir *et al.* 2023) can also help teachers identify student difficulties and offer strategies for correcting them. Some practical implications would be:

- Review students' work and provide specific and constructive feedback on their strategies and justifications.
- Identify strengths and suggest improvements
- Ask for additional justifications
- Identify and address common misconceptions about proportionality.
- Clear explanations
- Additional examples
- Provide opportunities for additional practice,
- Additional problems in the classroom
- Homework activities,
- Provide feedback on student performance.

4. Conclusion

Based on aim 1, which is: to analyze the level of knowledge about proportionality possessed by primary school teachers. The results of this study have revealed that most of the participants lack the necessary knowledge and skills to effectively teach the concept of proportionality. There is a clear lack of training in proportionality among primary school teachers and future teachers. This can negatively influence the learning of elementary school students. Teachers who are not well prepared to teach proportionality may transmit misconceptions, which can influence and limit students' development.

In order to achieve good training, adequate pedagogical strategies and resources are required to improve the teaching of proportionality. Teachers and future teachers must have access to relevant manipulative educational materials, clear didactic strategies, and adequate technological resources to enable them to teach proportionality in a way that is appropriate for students.

From aim 2, which is: to evaluate the level of knowledge about proportionality that students of Primary Education have, most of the participants use the rule of three in everyday life and in the classroom as the only method of solving proportionality problems since they have no knowledge of any other method. The rule of three is a decontextualized but simple method with which teachers get their students to give correct answers but without understanding what they are doing.

Based on objective 3, which is: to identify possible difficulties or misconceptions that both teachers and student teachers may have in relation to proportionality. As it has been observed, the participants have difficulties with the concepts of ratio and proportion, at a theoretical and practical level. In addition, most of the participants do not know how to differentiate between a situation of proportionality and one of non-proportionality, which implies that the students do not know how to differentiate them either, i.e. they do not know when they have to apply the necessary methods to solve such a problem.

It is very important to have good and continuous training, which is achieved by participating in professional development courses on the teaching of proportionality and its didactics, researching and using specialized educational resources on proportionality, such as textbooks and teaching materials, and participating in communities of practice where teachers can collaborate and share experiences related to the teaching of proportionality.

These lines of action can help teachers improve the teaching and learning of proportionality in Primary Education, fostering a deeper and more meaningful understanding of this mathematical concept. It is important that teachers adapt these recommendations to the specific needs and characteristics of their students.

It is very important to raise awareness of the relevance of proportionality and to promote its inclusion in the mathematics curriculum of Primary Education.

In the future, it would be interesting to study how this inadequate and improper teacher training is affecting their students, what consequences it is having on the students' education and how it could affect them in the future.

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