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The Development of Virtual Reality Media in Case Method Learning to Enhance Science Literacy and Habits of Mind for Prospective Physics Teachers in Achieving Sustainable Development Goals

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Abstract

This research aims to develop interactive learning materials for reflective microteaching to cultivate the professional character of prospective teachers. The study employs a development research design using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. Expert validation indicates that the media is highly valid, with scores of 75.01 (Valid) and 80.93 (Highly Valid). The feasibility of the media was assessed by lecturers applying Virtual Reality in the classroom using a case method learning model. The instructional design utilized a pretest-posttest group design involving 30 physics students (prospective physics teachers). After implementing the media, an evaluation was conducted to measure initial and final data on science literacy and Habits of Mind, which were then statistically analyzed. The statistical results for science literacy and Habits of Mind showed that the normality test (Shapiro-Wilk) was normally distributed, and the hypothesis test (paired samples) yielded a significance value of < 0.05, leading to the acceptance of Ha (Virtual Reality media in case method learning can enhance science literacy and Habits of Mind in prospective physics teachers). Based on data analysis, it can be concluded that: 1) the Virtual Reality media is valid and suitable for use in teaching, and 2) the media in case method learning can improve science literacy and Habits of Mind in prospective physics teachers, contributing to achieving sustainable development goals.

Keywords: *Case Method Learning, Science Literacy, Habits of Mind*

INTRODUCTION

The advancement of technology in education has led to the emergence of various innovations aimed at improving the quality of learning, one of which is the use of Virtual Reality (VR). VR, as a learning medium, provides an immersive and interactive learning experience, allowing students to explore scientific concepts more deeply and realistically (Merchant et al., 2014). Research shows that VR technology is capable of enhancing the understanding of abstract concepts that are difficult to explain through conventional methods, such as concepts in physics (Radianti et al., 2020). Another study shows that using VR in physics learning can boost students' understanding of abstract concepts. The interactive learning experience in a 3D environment helps students visually grasp the mechanisms behind challenging physics concepts (Merchant et al., 2014).

By bringing students into an interactive 3D environment, VR lets them explore complex ideas in ways that are tough to achieve with traditional methods. This immersive experience not only makes abstract theories easier to grasp but also helps students build a deeper and more intuitive understanding of the mechanics behind tricky physics concepts. Some other studies say that VR not only helps students understand physics concepts better but also boosts their learning motivation and engagement throughout the learning process (Johnson-Glenberg, 2018). With VR, students get a firsthand experience as if they're in a real-life situation, letting them observe physics phenomena more deeply. This doesn't just make learning more engaging; it also sparks curiosity and encourages them to want to learn more. This active involvement is crucial in supporting an effective learning process, especially in fields that need a deep understanding, like physics.

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In physics education, scientific literacy is a fundamental competency that prospective teachers must possess. Scientific literacy encompasses an understanding of scientific concepts, critical thinking skills, and the ability to apply scientific knowledge in everyday life (Bybee, 2014). Understanding scientific concepts is a fundamental aspect of scientific literacy. In physics education, scientific literacy helps prospective teachers understand the subject matter better and convey it effectively to students (Siswanto et al., 2023). For example, understanding concepts such as energy, force, and momentum will help future teachers relate these topics to everyday phenomena, like the movement of objects or the use of electrical energy at home. Prospective teachers with good scientific literacy can develop more creative and contextual teaching strategies, making physics content more engaging and relevant for students. This understanding includes mastery of various basic concepts in science, such as energy, matter, and ecosystems (Wulandari et al., 2021).

This skill has become really important with the rapid growth of science and technology. Science literacy isn't just about adding to someone's knowledge of science; it's also about developing critical thinking skills to evaluate information and make decisions based on scientific evidence (Pertiwi et al., 2018). This is relevant in the digital era, where information is easily accessible but not always accurate or based on scientific evidence. Moreover, scientific literacy also involves critical thinking skills essential for examining and evaluating information objectively (Sutiani et al., 2021). In today's information era, prospective physics teachers who are scientifically literate will be able to identify valid information from various sources and avoid spreading misinformation related to science. Therefore, scientific literacy becomes a crucial foundation in shaping prospective physics teachers who not only master the subject matter but also possess the necessary skills to support problem-based learning and decision-making grounded in data and scientific evidence (Akcay & Benek, 2024)

This is important because science-literate teachers can create relevant and engaging lessons, enabling students to understand the real benefits of science in their lives. With the development of curricula emphasizing mastery of 21st-century competencies, strengthening scientific literacy among prospective physics teachers is essential (Valladares, 2021) Strengthening science literacy also has the potential to create a long-term impact on society. Prospective physics teachers who have a deep understanding of science literacy will become agents of change, capable of educating younger generations to think critically and be open to the advancement of knowledge. This skill will not only enhance the quality of physics teaching in schools but also have a long-term impact on improving scientific understanding in the community (Ma et al., 2023). Additionally, improving science literacy among future teachers will help create a society more prepared to embrace new technologies and innovations, making them active participants in the advancement of scientific and technological civilization.

The improvement of science literacy through VR media is considered effective because VR provides a learning environment that closely simulates real-life situations, allowing students to directly practice physics concepts (Zacharia et al., 2008). The conventional learning approach, which usually relies on textbooks, static images, and verbal explanations, is often seen as less effective for fully explaining these concepts (Alkhabra et al., 2023). So, an innovative approach that allows for a deeper understanding through interactive visualization has become an essential need in modern physics education.

The use of case-based learning, or the Case Method, is becoming increasingly relevant in the education of prospective physics teachers. This method allows students to develop analytical and problem-solving skills by applying their knowledge to real-world situations (Herreid & Schiller, 2013). The integration of VR with the Case Method not only enhances conceptual understanding but also helps students develop habits of mind, such as critical and creative thinking skills (Costa & Kallick, 2008). The Case Method, as a problem-based learning approach, encourages students to analyze complex real-life situations, seek solutions, and make decisions. When combined with VR, which provides an immersive and interactive learning environment, this method can lead to a richer and more contextual learning experience (Asih et al., 2022). Further research also found that active interaction in a VR environment using the Case Method can enhance students' emotional engagement and learning motivation (Matovu et al., 2023).

Habit of Mind is a set of thinking habits that includes skills such as reflective, critical, and creative thinking, which are essential in the teaching profession (Costa & Kallick, 2009). Research shows that the Habit of Mind developed through active and contextual learning can prepare prospective teachers to face various challenges in the teaching process (L. W. Anderson, 2002). A study by Rikizaputra & Firda (2020) analyzed the Habit of Mind (HoM) among biology teacher candidates. The results showed that most students exhibited a moderate level of HoM, with an average score of 3.59 on a 5-point scale. This research emphasizes the importance of appropriate learning strategies to develop students' HoM, such as assigning independent tasks and practical activities relevant to real-world contexts. Another study by Sugandi & Maya (2019) examined HoM in mathematics teacher candidates. They found that the highest indicator was flexible thinking ability, while the lowest was in risk-taking and responsibility. This study highlights the need for learning methods that encourage students to take risks and be responsible in the teaching and learning process. The integration of VR in Case Method learning can enhance the Habit of Mind by providing a more dynamic and relevant learning experience (Makransky & Lilleholt, 2018).

The development of VR-based learning media is also aligned with the Sustainable Development Goals (SDGs), specifically Goal 4, which aims to ensure inclusive and quality education and promote lifelong learning opportunities for all (Nations, 2015). By integrating VR technology into learning media, this initiative not only enhances the accessibility of educational content but also promotes an immersive and interactive learning experience, creating a more equitable and engaging learning environment. This approach directly supports the SDGs' emphasis on inclusive education by providing learning tools that encourage active participation and continuous self-development for learners of all backgrounds at every level of education. VR can create an inclusive learning environment where all learners, including those with physical disabilities, can actively participate (Freina & Ott, 2015). With this technology, students from various backgrounds, including those with physical limitations, can engage in learning activities actively and equally. VR allows them to experience immersive learning without being hindered by physical constraints, opening up broader participation opportunities and enriching the educational process for everyone.

Additionally, VR can enhance learner engagement, which is a crucial factor in achieving optimal learning outcomes (Merchant et al., 2014). VR-based media offers a deep, interactive, and immersive learning experience, enabling students to understand abstract concepts more effectively through 3D visualization and simulation. This approach is especially beneficial for learning in complex fields such as science and technology, where challenging concepts can be explained more easily and engagingly.

Several studies have shown that the use of VR in learning can enhance students' motivation and learning outcomes, particularly in the field of science (Checa & Bustillo, 2020). This level of engagement can spark curiosity, making learning feel more relevant and engaging, which in turn boosts their intrinsic motivation to understand the lesson material. Additionally, the hands-on experience provided by VR helps reinforce understanding, as students actively interact with concepts rather than just passively receiving information, resulting in better retention and a deeper comprehension of scientific principles. Therefore, the development of VR media in Case Method learning is expected to be an innovative solution to improve the science literacy and habit of mind of prospective physics teachers, enabling them to be better prepared to contribute to the achievement of the SDGs (Makransky et al., 2016). Thus, the development of VR media in case method learning is expected to be an innovative solution for enhancing scientific literacy and the habit of mind among prospective physics teachers. Through VR technology integration, these future educators can gain a deeper, more interactive learning experience that strengthens critical thinking, problem-solving, and adaptability key components of the habit of mind. This approach not only prepares them to grasp complex physics concepts more effectively but also equips them with the skills needed to make meaningful contributions toward achieving the Sustainable Development Goals (SDGs) (Prayogi & Verawati, 2024). With improved scientific literacy and a progressive mindset, these prospective teachers will be better prepared to foster scientific awareness and sustainable practices in their future classrooms, ultimately supporting broader educational and global development objectives.

Additionally, the use of VR in physics education can also address the limitations of laboratory equipment, which are often difficult for all students to access (Zacharia et al., 2008). VR not only facilitates learning physics in a more interactive way but also ensures student safety, especially when dealing with topics involving complex and potentially hazardous processes or equipment. VR provides an efficient and safe alternative for learning physics concepts that require practical experiments (Jensen & Konradsen, 2018). VR offers an efficient and safe alternative for learning physics concepts that typically require practical experiments. It allows students to engage with complex and potentially hazardous scenarios within a controlled virtual environment, minimizing risks while maximizing access to interactive learning. Therefore, the development of VR media in Case Method learning is not only relevant for enhancing science literacy but also for preparing prospective physics teachers who are capable of adapting to technological advancements and global demands (Gavish et al., 2015). Through the use of VR technology, prospective teachers can gain a deeper understanding of how physics concepts are applied in real-world situations that resemble field conditions. At the same time, they can develop adaptive skills necessary for innovating and keeping up with the rapid changes in education and science.

METHODS

The type of research used is developmental research (Research and Development), commonly referred to as R&D. The R&D research method is used to produce a specific product and test the effectiveness of that product (Sugiyono, 2016). The media preparation design refers to media development based on the ADDIE model (Branch, 2009), which consists of five development stages: Analysis, Design, Development, Implementation, and Evaluation.

1. Preliminary analysis: This stage gathers relevant information regarding science literacy skills and Habit of Mind through field studies (observations of prospective teachers teaching directly) and literature reviews (examining literature to collect information related to the development of virtual reality learning media).

2. Design Stage: In this stage, the plan is to design VR media utilizing the Milea Lab application. The design steps are as follows:

a) Collecting materials

b) Gathering resources to be integrated into the application

c) Determining the scenario for using VR media

d) Developing the VR media

3. Development Stage: In this stage, the VR media is developed, followed by validation testing by subject matter experts and media experts. Revisions are also made based on the experts' recommendations.

4. Implementation Stage: This stage involves the application of VR media in the classroom and its trial with 30 students (prospective physics teachers). During this phase, measurements of science literacy and habit of mind will be conducted. The trial design uses a one-group pretest-posttest design, as shown in the following image.

Figure 1. One Group Pretest-Posttest Design

O_1	X	O_2

Explanation:

O1 = Initial data results for science literacy and habit of mind

O2 = Final data results for science literacy and habit of mind

X = Treatment using VR media in case method learning

5. Evaluation Stage: In this stage, a comprehensive evaluation of the VR media is conducted. The collected data is then processed using descriptive analysis and statistical tests, and the results are interpreted to derive the research conclusions.

Table of Validity Category

Score	Kategori
80 > x ≤100	highly valid
60 > x ≤80	Valid
40 >x ≤60	Fairly Valid
20 > x ≤40	Invalid
0 ≥ x ≤20	Highly Invalid

Table of N-gain Categories

N-gain Value	Category
g < 0,3	Low
0,3 ≤ g < 0,7	Medium
0,7≤ g < 1,0	High

RESULTS AND DISCUSSION

The Analysis Stage

Virtual Reality (VR) is an innovative technology that can be used in case method-based learning to enhance the science literacy and Habit of Mind of prospective physics teachers. The use of VR in learning enables students to experience realistic interactive simulations, thereby facilitating a deeper understanding of complex physics concepts (Merchant et al., 2014). In this context, VR not only provides an immersive learning experience but also encourages students to develop critical and reflective thinking skills, which are essential in the teaching profession (Hwang & Hu, 2013).

The researcher conducted observations on four 7th-semester pre-service teachers who were carrying out their Field Practice Experience (PPL). They were assigned the task of implementing case method-based learning using VR to teach physics concepts that had been studied in previous semesters The VR implementation was carried out in two stages for each student. In general, the issues found included the pre-service teachers' limited ability to optimally utilize VR technology, a lack of student engagement in active learning activities, and their limited ability to integrate physics concepts into case-based learning scenarios (Freina & Ott, 2015).

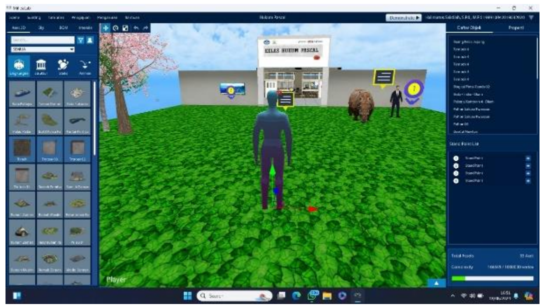
After each teaching practice session, students are given feedback by lecturers and peer students regarding areas of improvement and the necessary steps for the next session. However, the same issues often reoccur in subsequent practice sessions. This indicates the need for the development of interactive and reflective VR-based teaching materials, which can help prospective teachers make continuous improvements (Hussein & Nätterdal, 2015). In VR-based learning, recordings of teaching sessions can be reviewed to identify areas needing improvement, allowing for deeper reflection and more effective improvements (Martín-Gutiérrez et al., 2017).

The Design Stage

The design phase in the development of VR media based on the case method learning model involves determining the content and components to be included in the learning media. At this stage, clear learning objectives are formulated to enhance the science literacy and Habit of Mind of prospective physics teachers (Dalgarno & Lee, 2010). The use of VR in physics learning allows students to directly experience scientific concepts, which can strengthen their understanding and improve their critical and analytical thinking skills (Makransky & Lilleholt, 2018).

The interactive teaching materials developed consist of physics case scenarios simulated in a VR environment. These scenarios are designed to challenge students in solving complex problems related to physics concepts, thereby encouraging them to think critically and reflectively (Kavanagh et al., 2017).Additionally, the teaching materials also include individual and group tasks aimed at fostering collaboration and reflective discussion among prospective teachers (Mantovani et al., 2003).

In this design stage, other supporting components, such as formative and summative assessments, were also developed to ensure that the instructional media could achieve the desired objectives. These assessments were designed to measure the improvement in science literacy and Habit of Mind of prospective physics teachers after they used the VR media in learning (Makransky et al., 2019). By considering all these components, the VR-based instructional media is expected to have a significant positive impact on the professional development of prospective physics teachers and contribute to the achievement of the Sustainable Development Goals (SDGs) through quality education (Rieckmann, 2017).



Development Stage

Media Validation

No	Indicator	Score	Category
1	Visual Quality	76	Valid
2	Navigation and Interface	82,67	Highly Valid
3	User Engagement	78	Valid
4	Accessibility	88	Highly Valid
5	Responsiveness and Performance	80	Highly Valid
	Average	80,93	Highly Valid

Based on the validation results conducted by experts, the developed VR media received an average score of 80.93, categorized as "Highly Valid." In detail, the validity assessment covered visual quality (76, Valid), navigation and interface (82.67, Highly Valid), user engagement (78, Valid), accessibility (88, Highly Valid), and responsiveness and performance (80, Highly Valid). These results indicate that the developed VR media possesses excellent quality for use in education (Nieveen, 1999)

The Implementation and Evaluation Stage

a. Improvement in Science Literacy

Descriptive Data

	N	Min	Max	Mean
Pretest_Science_Literacy	30	25.00	45.00	33.3333
Posttest_Science_Literacy	30	65.00	80.00	73.0000
Valid N (listwise)	30			

Normality Test

		Shapiro-Wilk		
	Group's data	Statistic	df	Sig.
Pretest_Science Literacy	Case Method	.862	30	.001
Posttest_Science Literacy	Case Method	.836	30	.000

Hypothesis Test

Test Statistics[a]	
	Posttest_Science Literacy-Pretest_Science Literacy
Z	-4.839[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

The data on the improvement of science literacy was measured through pretests and posttests, which were analyzed using the N-gain test. The average N-gain obtained was 0.594, which falls into the "Moderate" category. This indicates a significant improvement in science literacy among prospective physics teachers after using VR media. The normality test results show that the data is normally distributed, allowing for hypothesis testing to be conducted using a t-test. The t-test results indicate a significant difference between the pretest and posttest scores, meaning that the use of VR media is effective in enhancing science literacy (Hake, 1998).

c. Improvement of Habit of Mind

Descriptive Data

	N	Minimum	Maximum	Mean
Habit_MInd_Awal	30	37.50	52.50	45.253
Habit_Mind_Akhir	30	57.50	91.25	78.795
Valid N (listwise)	30			

Normality Test

		Shapiro-Wilk		
	Group's data	Statistic	df	Sig.
Initial Habit of Mind	Case Method	.971	30	.561
Final Habit of Mind	Case Method	.958	30	.281

Hypothesis Test

		t	df	Sig. (2-tailed)
Pair 1	Initial Habit of Mind Final Habit of Mind	-38.891	29	.000

The improvement of Habit of Mind was also measured through pretests and posttests, resulting in an average N-gain of 0.618, which falls into the "Moderate" category. Similar to science literacy, the Habit of Mind data were normally distributed based on the normality test, allowing for hypothesis testing using the t-test. The results of the t-test indicate a significant increase in the Habit of Mind of prospective physics teachers after learning with VR media (Costa & Kallick, 2000)

DISCUSSION

Improvement of Science Literacy

The improvement of science literacy among prospective physics teachers after using VR media showed significant results. Science literacy, which is the ability to understand scientific concepts and apply them in everyday life, is crucial for prospective physics teachers as they are responsible for teaching these concepts to their students (Bybee, 2010). The use of VR media in physics education allows prospective teachers to experience abstract concepts directly and interactively, contributing to a deeper understanding (Merchant et al., 2014a).

According to research, the use of VR technology in science education can facilitate learning in ways that traditional media cannot achieve (Dalgarno & Lee, 2010). VR provides an immersive learning environment where learners can interact with 3D simulations that realistically represent physical phenomena (Johnson, 2016). This allows prospective physics teachers to explore concepts such as force, energy, and motion in a more intuitive manner, which in turn enhances their science literacy (Edwards et al., 2018)

Previous studies have shown that science literacy is not only related to the mastery of scientific concepts but also to critical thinking and problem-solving skills (Holbrook & Rannikmae, 2009). In this context, VR provides prospective physics teachers with the opportunity to develop these skills by presenting challenging learning scenarios that require problem-solving (Makransky & Lilleholt, 2018). For example, in VR simulations, students may be faced with situations where they must apply the laws of physics to solve practical problems, such as designing a bridge or predicting the trajectory of a projectile (Azevich, 2019)

Furthermore, the observed improvement in science literacy in this study can be attributed to higher learning motivation triggered by the use of VR. Motivation is a key factor in learning, and research indicates that immersive technologies like VR can enhance student motivation by providing a more engaging and enjoyable learning experience (Bower et al., 2014). Prospective physics teachers involved in this study reported feeling more motivated to learn and explore physics material when using VR media, which ultimately improved their science literacy (Zacharia et al., 2008).

In the context of teacher education, high science literacy is crucial because future teachers need to transfer this knowledge to their students. By enhancing their own science literacy through the use of VR, prospective physics teachers not only improve their ability to understand and teach physics concepts but also prepare themselves to become more effective educators in addressing educational challenges in the digital era (Keengwe & Bhargava, 2014). Furthermore, the use of VR in teacher training can assist in preparing them to integrate this technology into their teaching practices, which is increasingly important as technology adoption in education continues to rise (Mikropoulos & Natsis, 2011).

Enhancement of Habit of Mind

The enhancement of Habit of Mind among prospective physics teachers after the implementation of VR media also showed positive results. Habit of Mind, which refers to the tendency to think critically, reflectively, and creatively, is an important aspect of education because it determines how an individual processes information, solves problems, and makes decisions (Costa & Kallick, 2008). In the context of physics education, the ability to think critically and reflectively is crucial, especially when faced with complex problems that require a deep understanding of scientific concepts (Perkins & Tishman, 2001).

The use of VR in physics education allows for the development of better habits of mind through deep and interactive learning experiences (Dede, 2009). VR provides an environment where learners can experiment, make mistakes, and learn from their experiences, all of which are essential elements in the development of habits of mind (Gura, 2014). In VR simulations, prospective physics teachers are encouraged to think critically when faced with complex situations, such as analyzing the effects of various forces on an object or predicting the outcomes of interactions between objects (Gee, 2007).

The results of this study indicate that the average N-gain for Habit of Mind is 0.618, which falls into the moderate category, suggesting that the use of VR is quite effective in developing the Habit of Mind of prospective physics teachers (Hake, 1998). This demonstrates that VR not only serves as an engaging learning tool but also as a means to cultivate the thinking skills necessary for success in the fields of science and education (Ritchhart & Perkins, 2005). In the VR simulation, students are not only required to understand scientific concepts but also to apply them in real-world scenarios, which necessitates critical thinking and sound decision-making (Windschitl, 2003).

The observed increase in Habit of Mind in this study can also be linked to the enhanced engagement of students during learning (Gee, 2007). Research shows that when students are more engaged in the learning process, they are more likely to develop stronger Habits of Mind (Shernoff et al., 2003). VR, with its ability to create immersive learning environments, enhances student engagement by making learning more relevant and meaningful (Bogusevschi et al., 2020). For example, when prospective physics teachers use VR to visualize interactions among particles in a physical system, they are presented with situations that require critical thinking and in-depth analysis, ultimately reinforcing their Habits of Mind (Lindgren & Johnson-Glenberg, 2013).

Furthermore, the improvement in Habit of Mind aligns with literature indicating that technology-based learning can enhance critical and reflective thinking skills (Savery & Duffy, 1995). This is supported by findings showing that technology-based learning media, such as digital simulations, interactive software, and online learning platforms, can facilitate more in-depth and collaborative learning experiences. Through technology, students not only gain a better understanding of lesson material but are also more encouraged to analyze information critically, evaluate different perspectives, and reflect on their understanding within a broader context. Thus, technology serves not only as a learning aid but also as a catalyst in developing essential habits of mind to enhance critical and reflective thinking in today's information era. Technologies such as VR allow learners to experience complex and dynamic situations in a safe and controlled environment, where they can experiment and learn from their mistakes (Savin-Baden, 2007). In this context, VR serves not only as a tool to facilitate the learning of scientific concepts but also as a platform for developing the higher-order thinking skills necessary for success in the field of science (Schraw, 2001)

Thus, the enhancement of Habit of Mind through the use of VR in the education of prospective physics teachers not only positively impacts their ability to teach effectively but also their capacity to continue learning and developing as professionals (Paul & Elder, 2006). A strong Habit of Mind enables prospective teachers to be more responsive to their students' needs, to think creatively in designing instruction, and to continuously evaluate and improve their own practices (Anderson, 2006) This is a key element in building sustainable and quality education, which is one of the main objectives of the SDGs.

CONCLUSION

Based on the above explanation, the conclusions are as follows:

Virtual reality media is valid and feasible for use in teaching.

Virtual media in case method learning can enhance science literacy and the Habit of Mind of prospective physics teachers in achieving sustainable development goals.

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